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Radiological Survey Reports

FORMERLY UTILIZED MED/AEC SITES REMEDIAL ACTION PROGRAM

RADIOLOGICAL SURVEY OF THE NATIONAL GUARD ARMORY AT WASHINGTON PARK, 52ND STREET AND COTTAGE GROVE AVENUE, CHICAGO, ILLINOIS

September 19, 1977 - October 11, 1978

OCCUPATIONAL HEALTH AND SAFETY DIVISION
Health Physics Section
ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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Argonne, Illinois 60439

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RADIOLOGICAL SURVEY OF THE NATIONAL GUARD ARMORY AT WASHINGTON PARK, 52ND STREET AND COTTAGE GROVE AVENUE, CHICAGO, ILLINOIS

September 19, 1977 - October 11, 1978

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PREFACE AND EXECUTIVE SUMMARY

This is one in a series of reports resulting from a program initiated in 1974 by the Atomic Energy Commission (AEC) to determine the conditions of sites formerly used by the Manhattan Engineer District (MED) and the AEC for work involving the handling of radioactive material.* Since the early 1940s, the control of over 100 sites that were no longer required for nuclear programs has been returned to private industry or to the public for unrestricted use. A search of MED and AEC records indicated that for some of these sites, existing documentation was insufficient to determine whether the decontamination work done at the time nuclear activities ceased is adequate by current guidelines. The Illinois National Guard Armory at Washington Park, in Chicago, Illinois, is one such site. This facility, once used for uranium processing during the MED/AEC era, is now used as offices, classrooms, and storage and garage areas.

To determine if any contamination remains as a result of the MED/AEC activities, a comprehensive radiological assessment of the armory was conducted during the period from September 19, 1977, to October 11, 1978. Direct instrument surveys and smear surveys indicated that some contamination and radioactive materials were still present. Contamination or radioactive material was found at 82 locations in 18 rooms or areas throughout the National Guard Armory. However, some of this radioactivity was judged to be a result of later use, not MED/AEC operations. Contamination possibly resulting from MED/AEC activities was found at 73 locations in 11 rooms or areas throughout the Armory. Except for Rooms 1 and 260 (messhall) and the drainage system for the floors of Rooms 1 and 5, where contamination was widespread, most of the contamination consisted of small localized spots (less than 300 cm^2), mainly on floors. The contamination in Room 1 was extensive and involved about 30% of the ceiling and floor and 200 m^2 of concrete. The contamination in Room 260 (messhall) involved about 3 m^2 of the concrete floor. The contamination on the floors was not easily removable, but most of the contamination on the ceiling was easily removable when smeared. The

*The various types and sources of radiation mentioned in this report are discussed in more detail in Appendix 8.

contamination in the floor-drainage system for Rooms 1 and 5 consisted of about 2 m^2 of contaminated brick and sludge in catch basins 3 and 4.

Beta-gamma readings taken with a gas-flow proportional survey meter on the contaminated areas in Room 1 ranged from background to 3.4×10^5 dis/min-100 cm^2. The alpha readings taken in Room 1 with the same instrument ranged from background to 5.8×10^4 dis/min-100 cm^2. The highest Geiger-Mueller (GM) End-Window contact exposure-rate reading from contamination in Room 1 was 3.0 mR/h; no GM End-Window exposure-rate readings taken at 1 m were distinguishable from the instrument background of 0.03-0.05 mR/h.

The beta-gamma contamination levels detected in the rest of the National Guard Armory with the gas-flow proportional survey meter ranged from 1.7×10^3 to 3.1×10^5 dis/min-100 cm^2. The alpha readings at those locations ranged from background to 5.8×10^2 dis/min-100 cm^2. The highest GM End-Window contact exposure-rate reading in the rest of the National Guard Armory was 0.5 mR/h, with no GM End-Window exposure-rate readings taken at 1 m distinguishable from the instrument background.

Contamination was detected on 50 of the smears collected during the survey; 48 of them were from Room 1. The beta-gamma readings of smears ranged from background to 2.5×10^3 dis/min-100 cm^2, and the alpha readings ranged from background to 1.7×10^3 dis/min-100 cm^2.

The readings obtained from the instrument and smear surveys were compared with the standards and guidelines in the American National Standard N13.12, "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use," and the Nuclear Regulatory Commission "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material."

It is known that uranium processing took place at the National Guard Armory during the MED/AEC era. Additionally, through gamma-spectral analysis of a sludge/dirt sample from a catch basin, the contaminant was identified as predominately normal uranium. Hence, the limits for uranium have been used for comparative purposes. The limits for uranium as given in the ANSI Standard N13.12 are 5000 dis/min-100 cm^2 total, of which only 1000 dis/min-100 cm^2 can be removable. Contamination possibly due to MED/AEC occupancy was found to exceed these limits at 42 locations in 9 rooms or areas throughout the National Guard Armory. Four of these locations also exceeded "the maximum radiation level of 1.0 mrad/h at 1 cm or the average radiation level of 0.2 mrad/h at 1 cm" as given in the NRC Guidelines for surface contamination resulting from beta-gamma emitters. Room 1 contained 30 of the 42 locations of contamination that exceeded the ANSI limits. Nine of these were on the floor, one on a pillar, and 20 on overhead structures. Two of the Room 1 locations also exceeded the NRC Guidelines for maximum radiation levels associated with surface contamination. One of these was on the floor (2.0 mR/h) and the other on a catch basin manhole cover (3.0 mR/h). The contamination was in most instances found to be removable and available for transfer to other locations, but under current use conditions, the potential for significant radiation exposure to occupants of the armory from these sources of contamination is believed to be small.

Radon daughter concentrations determined by indoor air samples ranged from 0.0003 to 0.0193 Working Levels (WL), including background. Grab-sampling techniques were used to collect the samples at selected locations, including the areas where contamination had been found during the direct surveys. Under the Surgeon General's Guidelines in 10 CFR 712, no need for remedial action is indicated when concentrations of radon daughters are less than 0.01 WL above background concentrations. The concentrations measured in the National Guard Armory air samples indicated normally expected background fluctuations. Radon concentrations, as determined from the radon-daughter measurements, ranged from 0.03 to 1.93 pCi/ℓ, well below the concentration guide of 3 pCi/ℓ for an uncontrolled area as given in the Department of Energy's "Requirements for Radiation Protection". No long-lived radionuclides were detected on any air sample.

Soil samples taken about the grounds and within the drainage system of the National Guard Armory to determine the presence of any radionuclides that could have been spilled or released during MED/AEC activities contained uranium concentrations ranging from less than 0.1 to 3.6 pCi/g. Background samples taken from the Chicago area indicated concentrations of natural uranium ranging from 0.6 to 2.2 pCi/g. Even though some of the samples collected about the armory exceeded the 2.2 pCi/g maximum measured in the background samples, the armory readings are most probably not a result of contamination. Since fertilization of the soil with inorganic compounds can increase the levels of uranium and thorium, these slightly elevated readings could have been a result of fertilization rather than residual contamination.

Analysis of the sludge/dirt sample taken from the drainage system for the floors of Rooms 1 and 5 indicated elevated levels of uranium (1.1×10^4 pCi/g, normal uranium). There now are no standards specifying a limit for uranium in soil, but, the measured uranium concentration in the sludge/dirt sample does exceed the proposed interim soil limit of 40 pCi/g for decommissioning and decontamination projects. (Ref. 1 and Appendix 6).

Potential radiation doses resulting from exposure to the radioactivity remaining from MED/AEC use of the armory were calculated for a pathway that could result in the presumed maximum 50-year dose commitments from inhalation/ingestion of contaminants. The internal radiation 50-year dose commitments from potential inhalation/ingestion of contamination remaining from MED/AEC activities were calculated to be 2.5 mrem to the lung, 0.51 mrem to the bone, 0.12 mrem to the kidney, and 0.031 mrem whole-body. Each of these is less than 0.5% of the appropriate standards for an individual in an uncontrolled area.

In order to reduce the potential for radiation exposure, remedial measures such as stabilization of the contamination in place would be applicable as a short-term measure. In order to reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution would involve decontamination by removal of the radioactive residues from the 11 rooms or areas in the facility.

This survey was performed by the following Health Physics personnel of the Occupational Health and Safety Division, Argonne National Laboratory, Argonne, Illinois: R. A. Wynveen, W. H. Smith, C. Boggs Mayes, P. C. Gray, and D. W. Reilly

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RADIOLOGICAL SURVEY OF NATIONAL GUARD ARMORY AT WASHINGTON PARK, 52nd STREET AND COTTAGE GROVE AVENUE, CHICAGO, ILLINOIS

ABSTRACT

A comprehensive radiological survey was conducted at the Illinois National Guard Armory at Washington Park in Chicago. This facility, used for uranium processing during the MED/AEC era, is now used as offices, classrooms, and storage and garage areas.

The survey was undertaken to determine the location and quantities of any radioactive materials remaining from the MED/AEC operations. Survey measurements included alpha and beta-gamma contamination determinations, both fixed and removable; beta-gamma exposure readings at contact and at 1 m; concentration estimates of radon daughters; and concentration determinations for ^{137}Cs, the ^{232}Th decay chain, the ^{226}Ra decay chain, and uranium in the soil on the site.

Forty-two spots of contamination in nine rooms or areas exceeded the allowable limits for uranium as given in the ANSI Standard N13.12. In most instances, the contamination was found to be removable and available for transfer to other locations. However, under current use conditions, the potential for radiation exposure to occupants of this building from these sources of contamination is small.

Concentrations of radon daughters in the air in the building, as measured by grab-sampling techniques, were less than the limit of 0.01 WL above background as given in the Surgeon General's Guidelines in 10 CFR 712. No long-lived radionuclides were detected in any air sample. Concentrations of radionuclides in soil samples collected around the facility indicated essentially background levels.

The presumed maximum 50-year dose commitments from potential inhalation/ingestion of residual contamination were calculated to be 2.5 mrem to the lung, 0.51 mrem to the bone, 0.12 mrem to the kidney, and 0.031 mrem whole-body; each of these is less than 0.5% of the appropriate standards for an individual in an uncontrolled area.

In order to reduce the potential for radiation exposure, remedial measures such as stabilization of the contamination in place would be applicable as a short-term measure. In order to reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution would involve decontamination by removal of the radioactive residues from the 11 rooms or areas in the facility.

INTRODUCTION

To resolve a critical space problem suffered by the Manhattan Engineer District, the United States Government leased from the State of Illinois the 124th Field Artillery Armory (presently the Illinois National Guard Armory at Washington Park) at 52nd Street and Cottage Grove Avenue in Chicago, Illinois, for work involving radioactive material. Beginning in March 1942, the building was used jointly by the MED Metallurgical Laboratory and the University of Chicago. The AEC terminated use of this facility in 1951, and the property was returned to the State of Illinois.

Personnel involved with the armory during the MED/AEC era recalled that some type of uranium processing was conducted there and that the grandstands surrounding the armory arena were used for storage of radioactive materials.* The use of the arena could have involved both the chemical processing and metal casting of uranium. After MED use of the armory ceased, contaminated dirt from the arena was removed. No record could be found of where the dirt was taken. Later, more dirt was removed from the arena and replaced with a concrete pad. Conversations with personnel involved with the facility also revealed that there was an effort to decontaminate some of the bleachers in the arena. However, no reports of radiation surveys or decontamination efforts conducted at the facility upon termination of MED/AEC activities could be found. It was, therefore, requested by the Energy Research and Development Administration, Chicago Operations Office, that a comprehensive radiological survey of the armory should be undertaken to determine if any detectable radioactive contamination remains as a result of the MED/AEC operations.

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*See Appendix 8 for a detailed discussion and definitions of the various terms and concepts mentioned in this report relative to types of radiation, exposures, doses, and similar topics.

The survey was performed on an intermittent basis between September 19, 1977 and October 11, 1978.

The Illinois National Guard Armory is presently occupied by the Illinois National Guard and houses the 1st Battalion, 178th Infantry and the 2nd Battalion, 122nd Field Artillery. It is currently used for offices, classrooms, and storage and garage areas.

SURVEY AND ANALYTICAL TECHNIQUES

General

A radiological survey of the armory was performed on all accessible floors and original walls to a height of 2 m (7 ft).* A representative selection of accessible overhead structures, such as ceilings, pipes, vents, and light fixtures, were also surveyed. In many areas, the floors and walls had been retiled or painted after the MED/AEC era. Even though these were not the original surfaces, these areas were surveyed with instruments that have some capability to detect potential beta-gamma activity on the underlying surfaces. Locations of accessible areas surveyed are indicated in Table 1 and Figures 2 through 26. (Rooms 1 through 199 are on the first floor, Rooms 200 through 299 on the second floor, Rooms 300 through 317 on the third floor, and Room 401 is on the fourth floor.)

Instrumentation Used for Direct Survey

Five types of survey instruments were used in the direct surveys. An Eberline gas-flow proportional probe (FM-4G) with a detection area of 325 cm^2 and using the Eberline PAC-4G-3 electronics was used to survey the floors. A PAC-4G-3 with a hand-held gas-flow proportional probe and with a detection area of 51 cm^2 was used to survey the walls and other areas inaccessible with the floor monitor. An Eberline Model 530 Geiger-Mueller (GM) detector with an

*When metric units are followed (in parentheses) by English units, the measurements were originally made in English units and then converted into metric. In cases where only metric units are given, the values were either originally given in metric, or resulted from calculations involving numbers previously converted from English into metric.

Eberline HP-190 end-window probe was used to measure the contact exposure rate (mR/h) of the contaminated areas. This instrument also was held 1 m (3 ft) above the floor to determine general ambient background radiation levels throughout the surveyed area.

Two other instruments were introduced toward the completion of the survey and also were used to detect the presence of any contamination in the catch basins in the armory. One, an Eberline Pulse Rate Meter Model PRM-5-3 with a Model PG-2 Low Energy Gamma Scintillation Detector, was used to detect low-energy x and gamma radiation. The other, an Eberline Micro R/h Scintillation Meter Model PRM-7, was used to detect higher energy gamma-rays.

All five instruments are described in more detail in Appendix 1.

Although ^{239}Pu and ^{90}Sr-^{90}Y standards were used to calibrate the gas-flow instruments, it should be noted that the numerous isotopes that could be encountered exhibit emission energies differing from those of the standards used in the calibration. When detecting known isotopes that emit alpha and beta energies differing from those of the standards, such as normal uranium, a conversion factor for those particular radionuclides was developed to determine the appropriate yield. (The methods used to determine the conversion factors are described in Appendix 2.) All readings of disintegrations per minute per 100 cm^2 (dis/min-100 cm^2), as reported in Table 1, are equated to normal uranium, unless otherwise stated. It should also be noted that since calibrations are to infinitely-thin flat-plate standards, all reported readings should be regarded as minimal values; no corrections were made for absorption by surface media within the armory.

When possible, the isotopes of contamination were identified by performing a gamma-spectral analysis (using a multichannel analyzer described in Appendix 1), on the contaminated item or on a sample of material taken from the contaminated area.* This instrument, along with all other survey and sampling devices, was housed in a mobile laboratory, a converted motor home.

*Such analysis was performed on one sample collected during the survey.

Smear Surveys

Dry smears were taken at selected locations throughout the National Guard Armory facility. Smears were taken on original structures and components such as walls, floors, pipes and vents. All standard smears were taken with Whatman No. 1 filter paper, 4.25 cm in diameter. A standard smear is performed by applying moderate pressure by the tips of the first two fingers to the back of the filter paper and rubbing the paper over the surface. Smears of about 930 cm^2 (1 ft^2) were normally taken. A smear of 100 cm^2 was taken if an area or object had an instrument reading higher than normal background, or if there was excessive dirt or dust in an area.

Two different instruments were used to measure (count) the contamination on the smears. They were first counted in groups of ten using a 10-wire flat-plate gas-flow proportional detector developed by ANL. The instrument detects alpha and beta particles and x- and gamma-rays. Additionally, at least one smear of each group was removed and counted in the more sensitive Nuclear Measurements Corp. 2π Internal Gas-Flow Proportional Counter (PC counter) using an aluminized Mylar cover (Mylar spun top) over the smear. All smears from areas or objects with elevated direct readings and, smears in groups indicating readings above the instrument background levels in the 10-wire assembly were individually counted in the PC counter. Smears were counted in each detector for both alpha and beta-gamma activity. These instruments are described in detail in Appendix 1.

In addition to collection of standard smears, a 100-g helium weather balloon (see Figure 29) was used in the arena to obtain smears of overhead structures (beams) that were about 27 m high. A small wooden cross frame was attached to the base of the balloon, and at one end of the cross frame was a small wooden block (covered with a foam pad) used to hold the smear paper. The smear paper used for the balloon smears was Whatman No. 1 paper, 15 cm in diameter. Control strings were attached to the wooden cross-frame to maneuver the balloon so smears could be obtained. The control strings were maneuvered to apply pressure while the smear was being taken. A 5-cm diameter portion of the filter paper was then cut and counted in the PC counter for both alpha and beta-gamma activity.

The smear-count conversion factors used to convert instrument counts to disintegrations of a particular isotope for all the smears are given in Appendix 2. Unless otherwise indicated, all contamination on the smears reported in Table 1 is equated to normal uranium, as described in Appendix 2.

The results of the instrument surveys and smears are given in Table 1, and the locations of elevated instrument readings and smear locations are shown in Figures 2 through 26. Since the contamination was widespread in Room 1, Figure 2 includes only the locations where elevated direct instrument readings and/or smear contamination was found.

Air Samples

Air samples were collected with a commercial vacuum cleaner modified at ANL for use as a particulate air-sampling device. A flow rate of 40 cubic meters per hour (m^3/h) was used. A 10% portion (5 cm in diameter) was removed from the filter media after collection and counted for both alpha and beta-gamma activity in the PC counter, using a Mylar spun top. The counting results were used to determine radon and radon daughter concentrations and the presence of any long-lived radionuclides. Information and assumptions used to determine the radon daughter concentrations are presented in Appendix 3; the results are given in Table 2, and the locations where air samples were collected are shown in Figures 2 through 24.

Soil Samples

Environmental soil corings were collected at selected undisturbed locations outside the National Guard Armory to detect any deposition of radioactive material that could have been spilled or released during MED/AEC activity. Nine environmental soil samples were taken from the grounds adjacent to the armory; the locations are shown in Figure 28. Uranium-fluorometric and gamma-spectral analyses were conducted on these soil samples. The corings were taken with a 10 cm (4 in.) diameter, 15 cm (6 in.) long, right-circular cylinder cutting tool commonly used to cut golf-green holes. Each core was 30 cm long, and each was divided into four segments. Starting from the surface, three separate 5 cm segments were cut, bagged, and marked A, B, and C, respectively; the final segment of 15 cm was marked D (see Figure 31).

The segmented coring technique was used to determine if any contaminant migration had occurred, to reduce the dilution of upper-level soil with the lower-level segments with respect to the surface deposition of the contaminants (or vice versa), and to reveal if any overburden or backfill material had been added over the years.

The soil samples were prepared at Argonne National Laboratory and shipped to a commercial laboratory (LFE Environmental Analysis Laboratories) for radiochemical (fluorometric) and gamma-spectral analyses. Their analysis procedures are described in Appendix 4. As shown in Figure 31, sample preparation consisted of weighing the samples and then drying them for about 24 hours at 80°C. All samples were then reweighed, placed into mill jars (8.7 ℓ), and milled until a sufficient amount of the soil sample would pass a No. 30 standard (600-micron mesh) stainless steel sieve. At no point were the rocks and solid material ground or pulverized, since this material would act as a diluent and, hence, lower the reported concentration of deposited radioactive material. The rocks and dross and the sieved material were segregated, bagged, and weighed separately (weights are given in Table 3).

Aliquots of the sieved material were loaded into screwtop plastic containers. The amount placed in the containers varied according to the type of analysis to be performed--100 g for gamma-spectral and radiochemical (fluorometric) analysis and 10 g for radiochemical (fluorometric) only.

Every effort was made throughout the sample preparation operations to eliminate cross-contamination. Soil samples suspected of containing elevated amounts of radioactivity were processed in separate equipment from that used to process the soil samples considered to contain background levels. Additionally, all items of equipment were thoroughly scrubbed and air dried before introduction of the next sample.

In addition to the nine environmental soil samples, a dirt/sludge sample (3-S10) was taken from the drainage system for the floors of Rooms 1 and 5. This sample was taken from the sediments at the bottom of Catch Basin 3 (see Figure 27 for location). The sample was collected with a 1.9 cm diameter pipe section driven about 5 cm into the residual sludge that had accumulated in the catch basin over the years. When the pipe was extracted from the deposits, the core sample remained in the pipe until shaken into a plastic bag. The preparation of this sample was similar to that described above for the environmental soil samples. However, because of its relatively small mass, the sample was milled with a mortar and pestle prior to sieving. Aliquots of the sieved material were loaded into screwtop plastic containers and sent to the Analytical Chemistry Laboratory at ANL for analysis. Eight grams were sent for gamma-spectral analysis and 2 g for radiochemical (uranium-fluorometric and uranium mass spectrometry) analysis.

Results of the analyses of the soil samples and of the sludge/dirt sample are shown in Table 4. Background data for comparison with the soil sample analyses were obtained from a number of soil samples collected in the Chicago area (see Table 5). This information was obtained from the Environmental Monitoring Section of the Occupational Health and Safety (OHS) Division of Argonne National Laboratory.

SURVEY RESULTS

General

The results of the radiological survey are discussed in this section. The PAC-4G-3 instrument readings and smear results have been normalized to units of disintegrations per minute per 100 square centimeters (dis/min-100 cm^2) using the factors derived in Appendix 2 and are equated to normal uranium, unless otherwise stated. The PAC-4G-3 readings and smear data are reported in net count rates; i.e., the background count rates have been subtracted from the gross count rates prior to conversion to dis/min-100 cm^2. Any alpha contributions have been subtracted from the readings taken in the beta mode so that the corrected values reflect only the beta-gamma readings. The GM exposure rates given in Table 1 include the instrument background of 0.03-0.05 mR/h.

Room background levels varied somewhat, due in part to differences in the construction materials used. The average background readings for all modes of operation of the instruments used are given in Appendix 1.

The fraction of surface areas accessible for survey varied from room to room. The percentages of the areas accessible for survey are indicated in Table 1. The average percentage of the total area that was accessible was 80% for the floors and 70% for the walls.

Instrument and Smear Surveys

Radioactivity, i.e., measurements indicating above background levels, was found at 82 locations in 18 rooms or areas throughout the National Guard Armory. (See Table 1 and Figures 2 through 26 for the maximum instrument readings at these locations.) Some of this radioactivity was determined to have resulted from later use, not MED/AEC operations. For example, radioactive sources and other items (including a radium dial, radioluminescent radio knobs, a gas mantle containing thorium, and radioluminescent compass dials) not related to MED/AEC operations were found in Rooms 3D, 101A, 121, 141, 144, 147, and 150.

Contamination possibly present as a result of the MED/AEC occupancy was found at 73 locations in 11 rooms or areas throughout the National Guard Armory. With the exception of Rooms 1 and 260 (messhall), and the drainage system for the floors of Rooms 1 and 5, the contamination consisted of small localized spots ($\leq$ 300 cm^2), found mainly on the floors. The contamination in Room 1 was extensive (see Figures 2a and 2b). Much of the ceiling and floor of this room was found to be contaminated, especially toward the southeastern side of the room, where most of the contamination was located. About 30% of the concrete floor and ceiling areas were involved, representing about 200 m^2 of concrete. The areas of contamination on floors were, for the most part, spots of contamination, but the ceiling areas were more widespread. Most of the ceiling in the southeastern corner was contaminated. The PAC beta-gamma contamination levels in Room 1 ranged from background to 3.4×10^5 dis/min-100 cm^2. The maximum beta-gamma reading, 3.4×10^5 dis/min-100 cm^2, was at location 104 on a catch basin manhole cover. The highest GM contact exposure rate reading of 3.0 mR/h was also on this manhole cover. The PAC alpha contamination levels in Room 1 ranged from background to 5.8×10^4 dis/min-100 cm^2. The maximum alpha reading, 5.8×10^4 dis/min-100 cm^2, was at location 121 on the ceiling. No GM exposure-rate readings taken at 1 m were distinguishable from the instrument background of 0.03-0.05 mR/h.

The PAC beta-gamma contamination levels detected in the rest of the National Guard Armory ranged from 1.7×10^3 to 3.1×10^5 dis/min-100 cm^2. The maximum beta-gamma reading outside Room 1, 3.1×10^5 dis/min-100 cm^2, was at location 821 on the floor of Room 260 (see Figure 16). The highest GM contact exposure rate reading of 0.5 mR/h was also found at this location. The PAC alpha contamination levels detected in the rest of the armory ranged from background to 5.8 x 10^2 dis/min-100 cm^2. The maximum alpha reading, 5.8 x 10^2 dis/min-100 cm^2, was at location 1081 on the floor of the 2nd-floor corridor (see Figure 19). No GM exposure rate readings taken at 1 m were distinguishable from the instrument background.

In addition to the room surveys, all accessible areas of the drainage system for the floors of Rooms 1 and 5 were surveyed (see Figure 27). Catch Basins 3, 4, and 6 were opened and surveyed with the PAC-4G-3 and PRM 5-3 instruments. As indicated in Table 1, contamination was detected in Catch Basins 3 and 4. The maximum beta-gamma contamination levels were 5.1 x 10^3 dis/min-100 cm^2 at locations 1199 and 1201 on the walls inside Catch Basins 4 and 3, respectively. Each location involved about 1 m^2 of contaminated brick and sludge. A gamma-spectral analysis was performed on a sample taken from inside Catch Basin 3. Results of the analysis indicated that the contaminant was predominantly normal uranium.* (See Figure 30 for the gamma spectrum.) Catch Basins 1, 2 and 5, were sealed shut and could not be opened. Micro R meter (PRM-7) readings, taken with the instrument in contact with the catch basin manhole covers, were not distinguishable from the instrument background readings of 5-7 μR/h. These catch basins are apparently connected to the Chicago sanitary sewer system.

Results of the smear survey indicated that 50 smears in the following rooms showed loose contamination:

- Room 1 (see Figs. 2a & 2b) — 48 smears of the floor and ceiling were contaminated. Location 121 of the ceiling had the highest level of contamination, 2.5 x 10^3 dis/min-100 cm^2 beta-gamma and 1.7 x 10^3 dis/min-100 cm^2 alpha. (See Table 1 for readings of other contaminated smears.)

*The term "normal uranium" refers to uranium which has been separated from its radioactive decay daughter products and other impurities, and which has the normal isotopic percent abundance as found in nature. The normal percent abundances are 0.0057% ^{234}U, 0.7196% ^{235}U, and 99.276% ^{238}U (Ref. 2). The less precise definition of normal uranium as 0.7% ^{235}U, 99.3% ^{238}U, and a trace of ^{234}U is sometimes used for brevity in discussions. The term natural uranium denotes uranium and all daughter products as found in its natural state in the earth, and is sometimes incorrectly referred to as normal uranium. Appendix 5 contains the detailed calculation of the specific activity of normal U.

- Room 1E (see Fig. 2) — Location 174 of the floor was background beta-gamma and 11 dis/min-100 cm^2 alpha.
- Room 5 (see Fig. 6) — Location 497 of the floor was 14 dis/min-100 cm^2 beta-gamma and background alpha.

No contamination statistically greater than the instrument background of the gas-flow proportional counters, as given in Appendix 1, was detected on any other smears. In Room 1, only locations of contaminated smears are shown in Figures 2a and 2b. In other rooms, all smear locations are shown in Figures 3 through 26.

Results of the instrument and smear surveys were compared with both the American National Standards Institute (ANSI) Standard N13.12, "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use," and the NRC's "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material" (see Appendix 6). Since normal uranium was identified in the building, the surface contamination limits for uranium were used for comparative purposes. The allowable limit in the ANSI Standard for uranium activity is 5000 dis/min-100 cm^2 total, of which only 1000 dis/min-100 cm^2 can be removable. These levels may be averaged over 1.0 m^2, provided the maximum activity in any area of 100 cm^2 is less than three times the limit value. The NRC Guidelines for uranium are stated as follows: the average is 5000 dis/min-100 cm^2 alpha, the maximum is 15,000 dis/min-100 cm^2 alpha, and the removable is 1000 dis/min-100 cm^2 alpha. The measurements used for the average may not be averaged over more than 1 m^2, and the maximum level applies to an area of not more than 100 cm^2. Also, the average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber. The ANSI Standard is identical to the NRC Guidelines for uranium; however, the ANSI limits do not exclude the determination of uranium by beta-gamma activity, whereas the NRC Guidelines are stated in terms of alpha activity only.

The 42 locations in which contamination possibly due to MED/AEC activities were found to be greater than the acceptable limits are listed in Table 6.

Air Samples

Results of the analyses of air samples collected at 34 selected locations are presented in Table 2. Techniques detailed in Appendix 3 were used to determine the radon-222 concentration and daughter working levels (WL) at each location. The results ranged from 0.0003 to 0.0193 WL and were within the range of values normally expected for background concentrations. Under the U.S. Surgeon General's Guidelines in 10 CFR 712 (see Appendix 6), concentrations of radon daughters of less than 0.01 WL above background do not indicate a need for remedial action. Radon concentrations, as determined from the radon-daughter measurements, ranged from 0.03 to 1.93 pCi/ℓ, well below the concentration guide of 3 pCi/ℓ for an uncontrolled area, as given in the Department of Energy's "Requirements for Radiation Protection." No long-lived radionuclides were detected on any air sample.

Soil Samples

Results of the gamma-spectral and uranium-fluorometric analyses performed on the samples by LFE Environmental Analysis Laboratories and ANL Analytical Chemistry Laboratory are listed in Table 4. The analyses indicated concentrations of uranium in environmental soil samples ranging from < 0.1 to 3.6 pCi/g. As indicated in Table 5, levels of natural uranium in background samples collected in the Chicago area ranged from 0.6 to 2.2 pCi/g. Even though the concentrations in some of the samples collected around the armory exceeded 2.2 pCi/g, the elevated concentrations were likely not a result of contamination resulting from MED/AEC activities. Since fertilization of the soil with inorganic compounds can result in increased levels of uranium and thorium, the slightly elevated concentrations detected in some of the armory samples could have been a result of fertilization rather than residual contamination. Results of the analyses of the sludge/dirt sample taken from the drainage system for the floors of Rooms 1 and 5 indicated a concentration of normal uranium of 1.1×10^4 pCi/g, far in excess of the proposed interim soil limit of 40 pCi/g (Ref. 1).

ESTIMATED EXTENT OF CONTAMINATION

Any estimate of the total mass and volume of radioactively contaminated material that would be generated by remedial action at the National Guard Armory is subject to many uncertainties. For example, one can only surmise as to the actual depth of contamination within concrete and brick. For the purposes of this report, it will be assumed that contamination on concrete or brick will require removal to a depth of 5 cm (2 in); contamination on the iron manhole cover to Catch Basin 3 will require the removal of the entire cover, estimated to have a mass of 68 kg (150 lb). These assumptions are believed to be conservative.

Estimates of the total activity of contaminated material are likewise subject to some uncertainties because of survey limitations. Unless otherwise stated, all readings of dis/min-100 cm^2 (as reported in Table 1) are equated to thin flat-plate standards. No corrections are made for absorption by surface media since any correction factors would, in themselves, only be rough estimates. Hence, estimates of activity in surface media could be underestimated.

Despite these uncertainties and limitations, estimates of volume, mass and activity have been made for the several types of material present and are presented in Table 7. The total would consist of an estimated 10.5 m^3 of material with a mass of 25,000 kg and an activity of 30 μCi.

DOSE AND POTENTIAL HAZARD EVALUATION

The survey data on surface contamination, external penetrating radiation, radioactivity on airborne particulates, and radioactivity in soil samples at the National Guard Armory may be evaluated in terms of the doses that potentially exposed persons could receive. The doses can then be compared to the appropriate standards and/or natural background radiation doses or used to estimate risks of health effects.

The appropriate radiation protection standards for external and internal exposure of individuals and population groups in uncontrolled areas are given in the Department of Energy's publication "Requirements for Radiation Protection" (see Appendix 6) and are expressed as the permissible dose or dose commitment annually (in mrem) beyond that received from background radiation and medical exposures.

Natural background radiation doses consist of an external penetrating dose from cosmic and terrestrial sources and an internal dose from the inhalation/ingestion of radioactivity from cosmogenic and terrestrial sources. The average annual natural background doses for the U.S. population are 54 mrem external and 28 mrem internal to the whole-body (soft tissue), 54 mrem external and 125 mrem internal to the lung, and 54 mrem external and 117 mrem internal to the bone (osteocytes) (Ref. 3). The total whole-body, lung, and bone doses are thus 82 mrem, 179 mrem, and 171 mrem per year, respectively. Background radiation is discussed in more detail in Appendix 8.

Estimates of radiological risks resulting from specific doses are usually based on risk factors as provided in reports by the International Commission on Radiological Protection (ICRP) (Ref. 4), National Research Council Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) (Refs. 5, 6), or United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (Ref. 7). By multiplying the estimated dose by the appropriate risk factor, one can obtain an estimate of the risk or probability of the occurrence of health effects such as cancers and hereditary effects to an individual or his descendants as a result of that exposure. The evaluation of risk factors is presently subject to large uncertainties and continual revision, and is the subject of considerable controversy. For these reasons, it will not be considered further.

Potential doses resulting from exposure to the radioactivity remaining from MED/AEC use of the armory were calculated for a pathway or scenario that could result in the presumed maximum internal radiation dose from inhalation/ingestion of radioactive material. Since no GM End-Window exposure readings at 1 m were greater than the instrument background, no external radiological hazard is envisioned from the contaminated items and areas. Additionally, since the radioactivity on airborne particulates and the radioactivity in environmental soil samples indicated natural background only, no pathways are considered here for those two sources. Therefore, only surface contamination is considered. Details of the dose calculations are discussed in Appendix 7; results are summarized below.

The presumed internal radiation dose commitments from potential inhalation/ingestion of contamination possibly due to the MED/AEC occupancy were calculated to be 2.5 mrem to the lung, 0.51 mrem to the bone, 0.12 mrem to the kidney, and 0.031 mrem to the whole-body. These are 50-year dose commitments and represent the total dose that would be accumulated in the body or specific critical organs over a 50-year period from inhalation/ingestion in the first year. Fifty-year dose commitments are always as large or larger than first-year annual doses; hence, all comparisons to annual dose standards are of a conservative nature. For the lung, bone, and kidney, these doses represent additions of 1.4%, 0.3%, and 0.15% to the 179-mrem, 171-mrem, and 82-mrem annual natural background lung, bone, and kidney doses, respectively, and 0.2%, 0.03%, and 0.008% of the 1500-mrem standard for an individual in an uncontrolled area. For the whole body, the calculated dose represents an increase of 0.04% to the 82-mrem annual natural background whole-body dose and 0.006% of the 500-mrem standard for an individual in an uncontrolled area.

In order to reduce the potential for radiation exposure, remedial measures such as stabilization of the contamination in place would be applicable as a short-term measure. To reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution would involve decontamination by removal of the radioactive residues from the 11 rooms or areas in the facility where contamination possibly resulting from MED/AEC activities was detected.

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3. National Council on Radiation Protection and Measurements. 1975. "Natural Background Radiation in the United States." NCRP Report No. 45.

4. International Commission on Radiological Protection. 1977. "Recommendations of the International Commission on Radiological Protection." Annals of the ICRP, Vol. 1. No. 3, ICRP Publication 26, Pergamon Press, New York.

5. National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR). 1972. "The Effects on Populations of Exposures to Low-Levels of Ionizing Radiation." National Academy of Sciences.

6. National Research Council, Committee on the Biological Effects of Ionizing Radiation (BEIR). 1980. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980." National Academy of Sciences.

7. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). "Sources and Effects of Ionizing Radiation, 1977 Report to the General Assembly." United Nations Publication E.77.IX.1.

FIGURE 1

SITE LOCATION OF ILLINOIS NATIONAL GUARD ARMORY

ANL-HP DWG. NO. 79-5

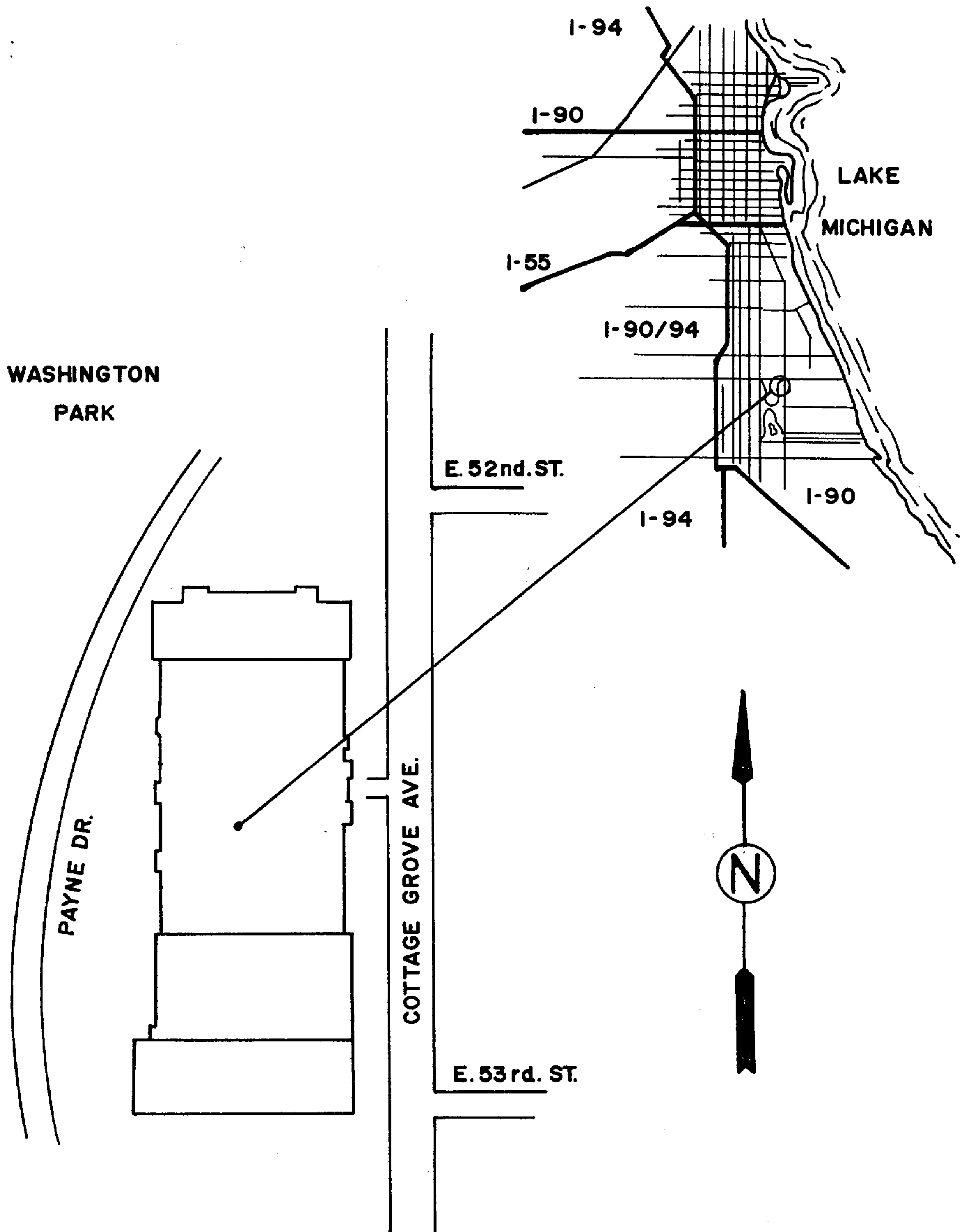


FIGURE 2A

AIR SAMPLE AND FLOOR SURVEY LOCATIONS IN ROOMS 1, 1A, 1B, 1C, 1D, 1E, 1F and 6

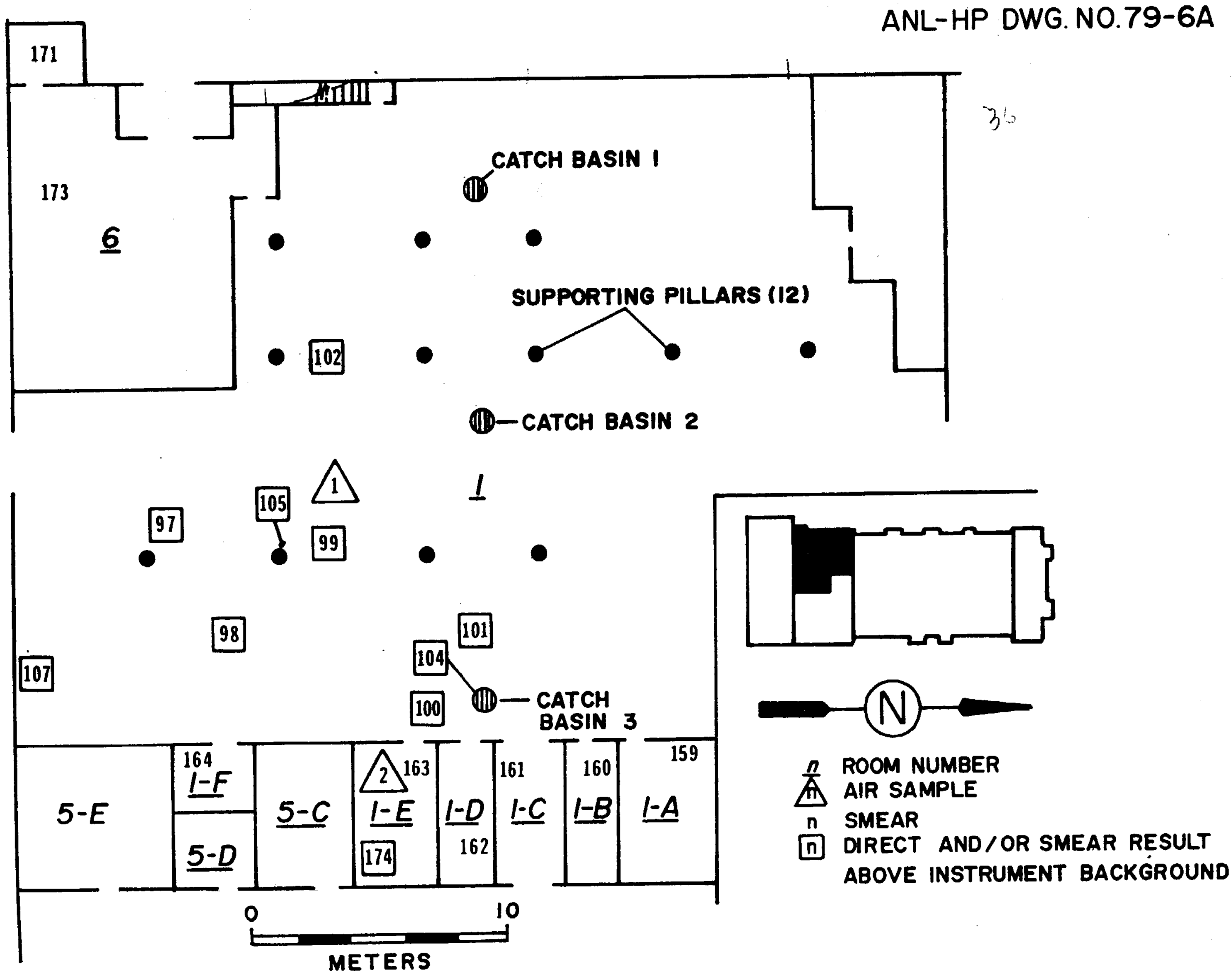


FIGURE 2B

OVERHEAD SURVEY LOCATIONS IN ROOMS 1, 1A, 1B, 1C, 1D, 1E, 1F and 6

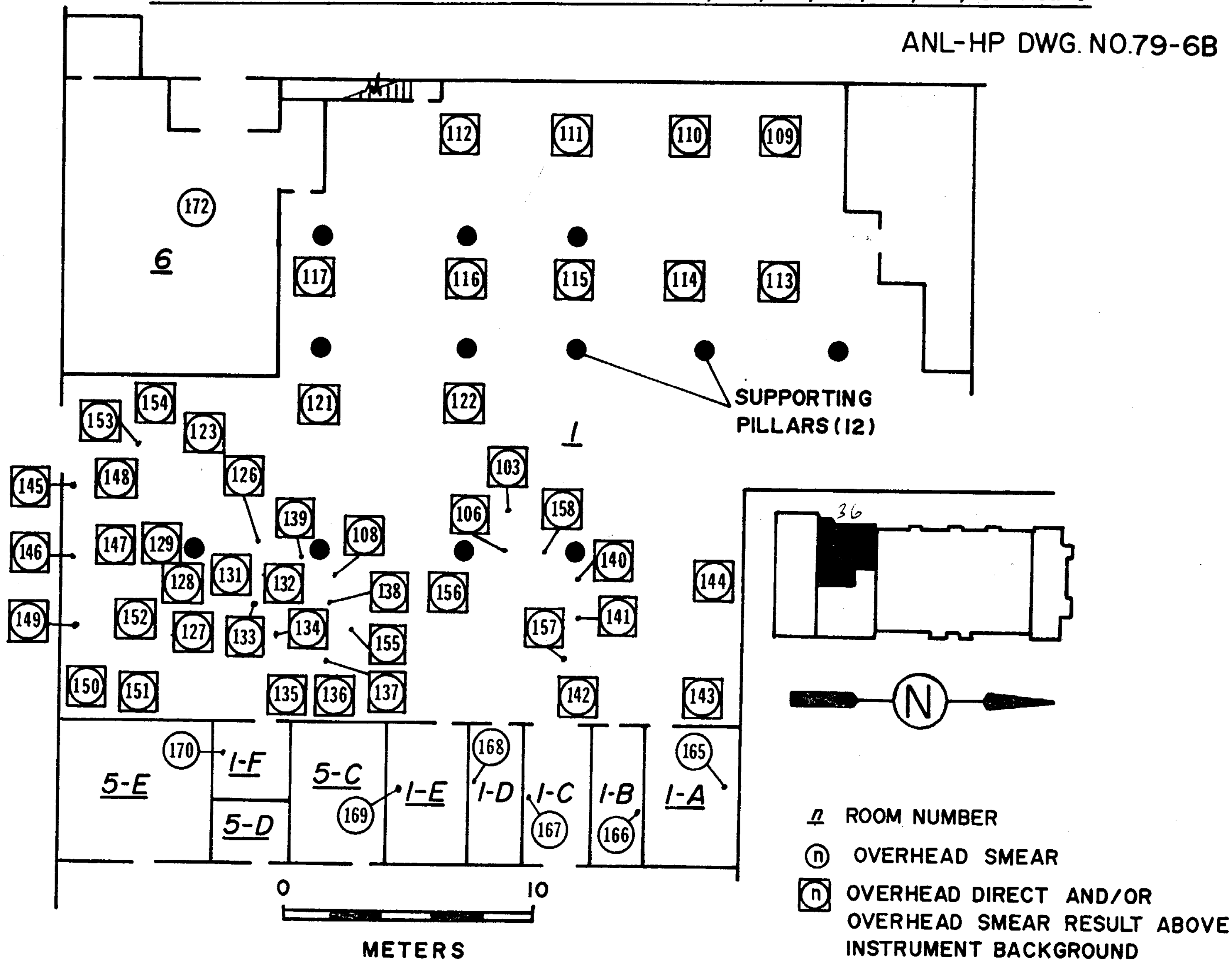


FIGURE 3

AIR SAMPLE AND SURVEY LOCATIONS IN ROOM 2

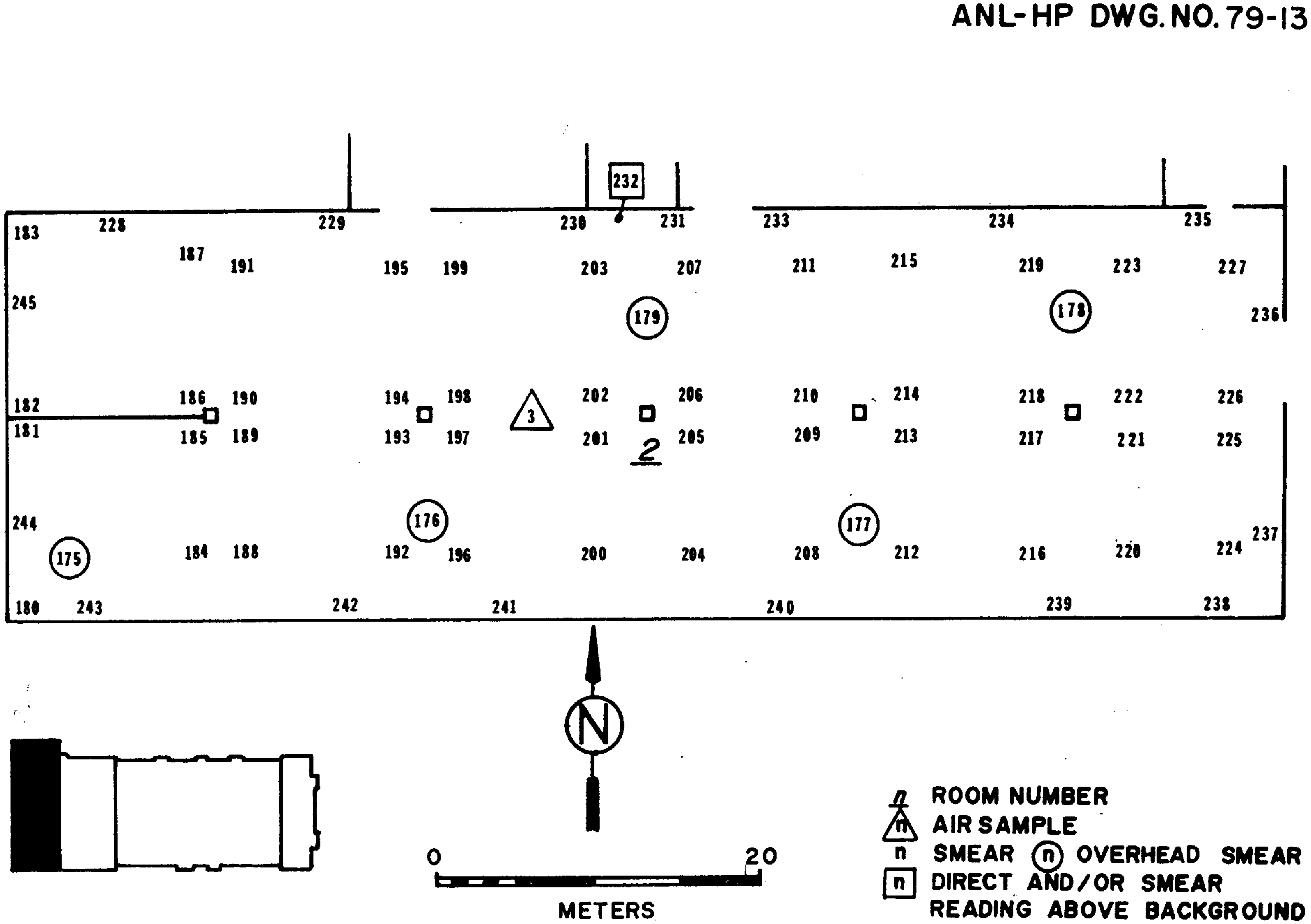


FIGURE 4

AIR SAMPLE AND SURVEY LOCATIONS IN ROOM 3 (ARENA)

ANL-HP DWG. NO. 79-12

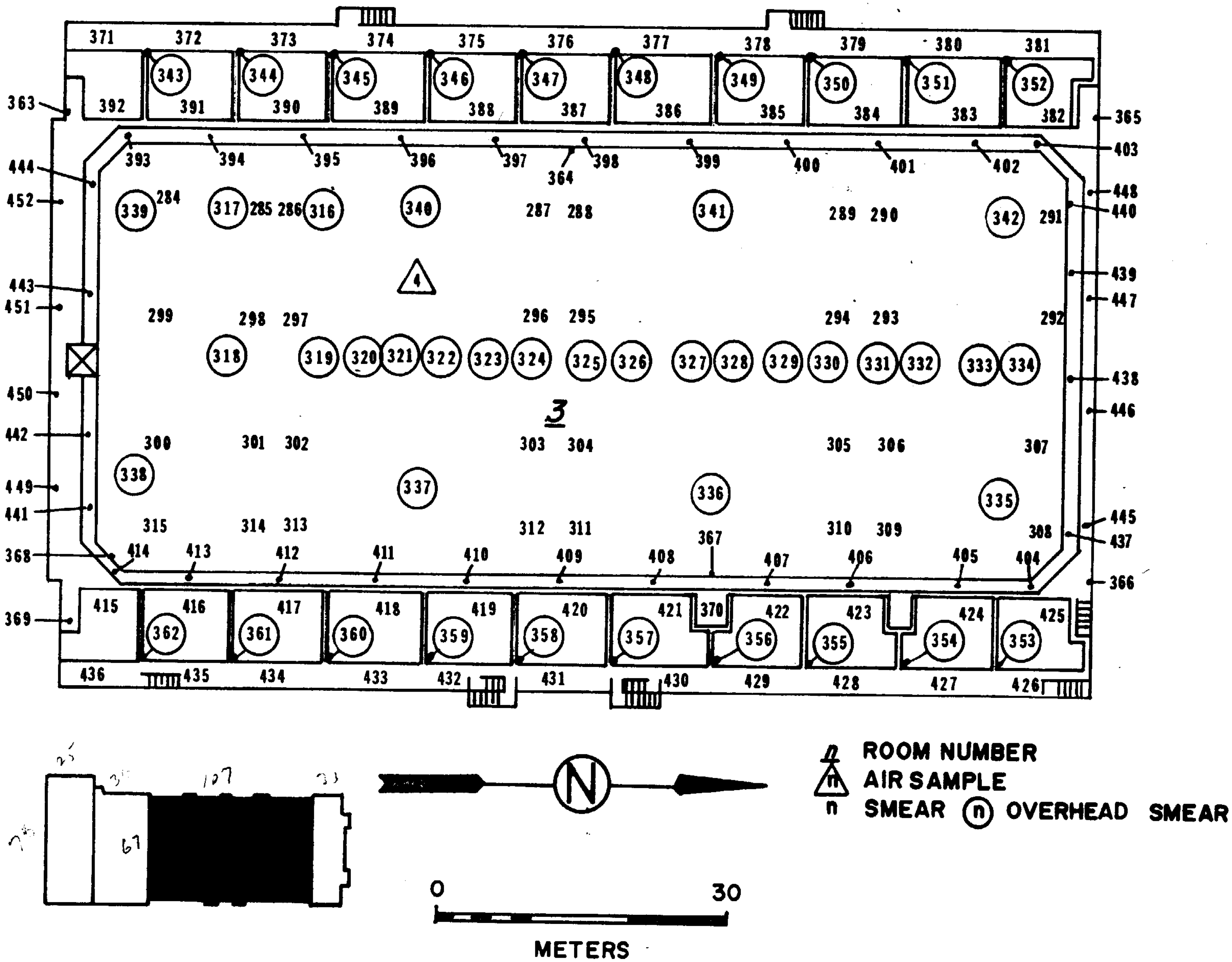


FIGURE 5

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 3A, 3B, 3C, 3D, 3E, and 3F

ANL-HP DWG. NO. 79-14

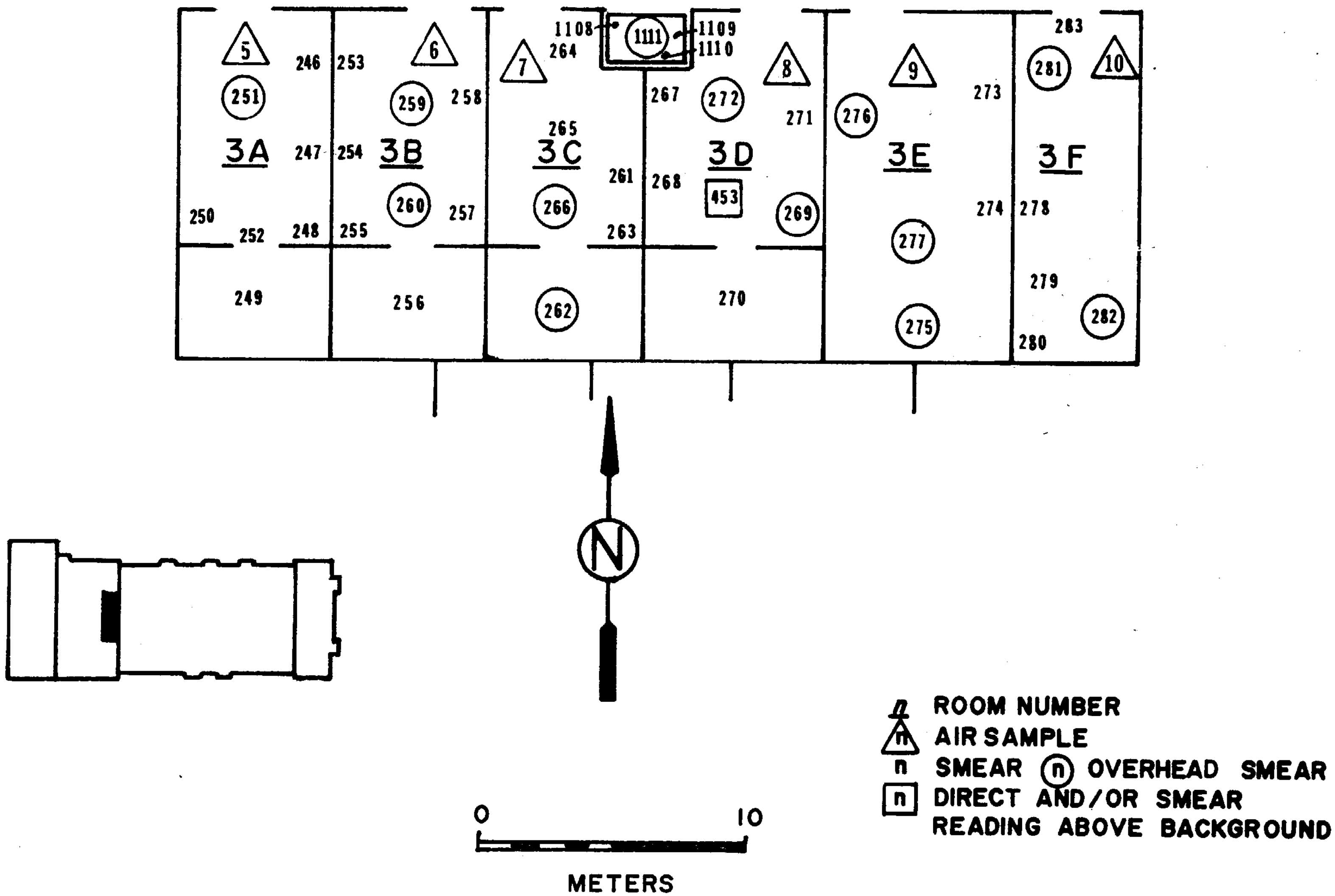


FIGURE 6

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 5, 5A, 5B, 5C, 5D and 5E

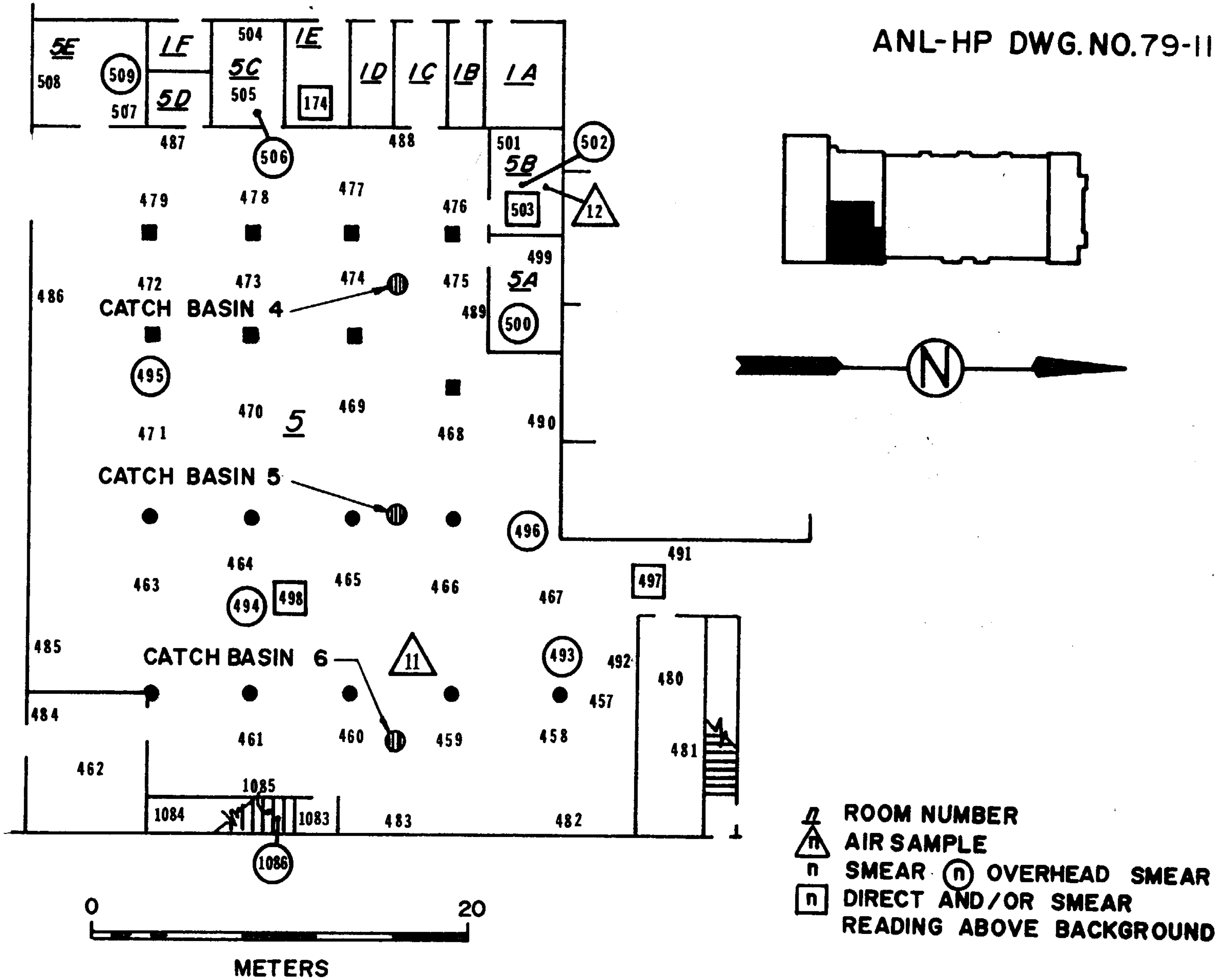


FIGURE 7

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 101, 101A, 102, 103, 104, 105
146A, 147, 147A, 147B, 148, 149 and NORTH EAST LOBBY

ANL-HP DWG. NO. 79-15

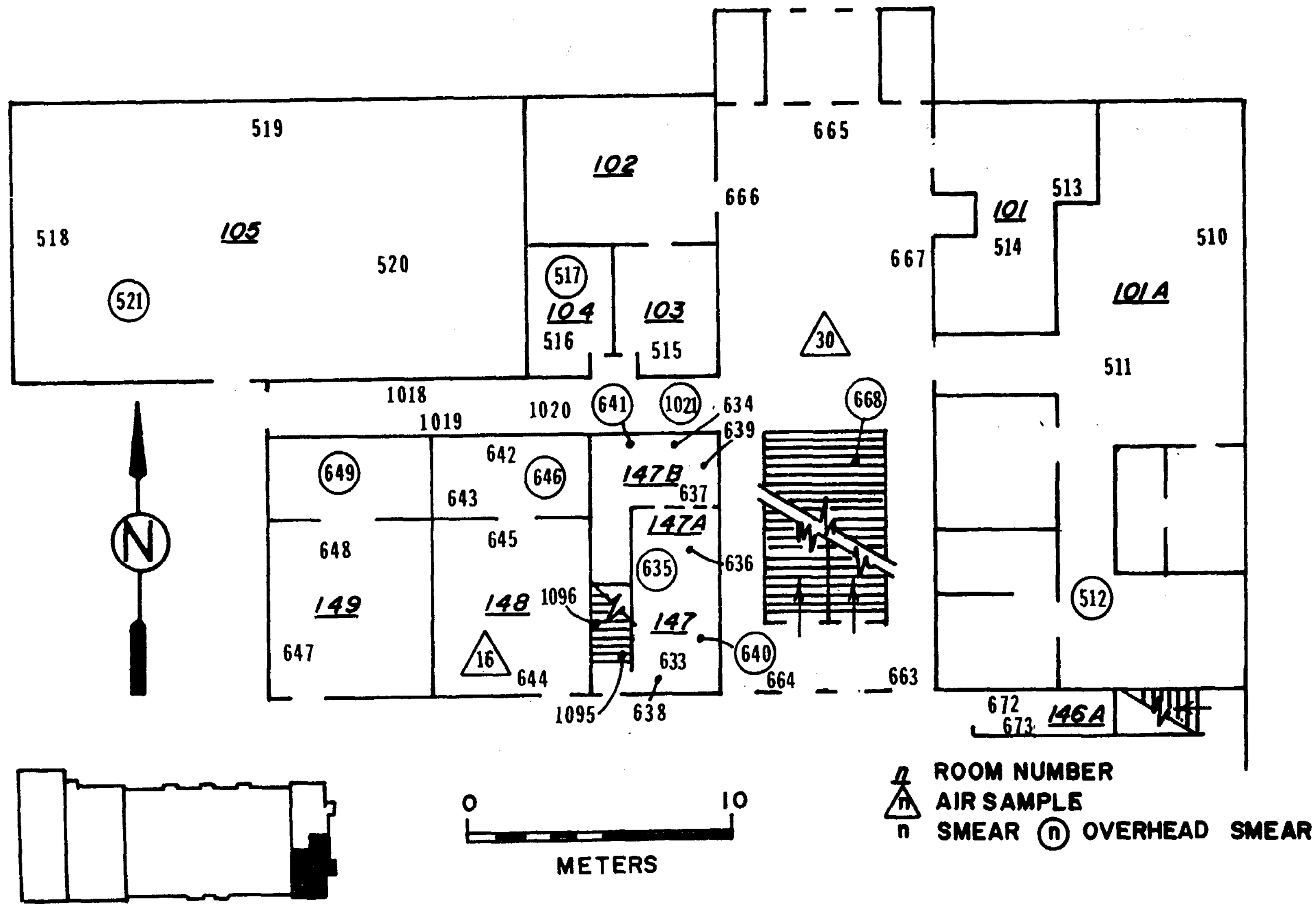


FIGURE 8

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 106, 107, 108, 108A, 109, 150, 151, 152 and NORTH WEST LOBBY

ANL-HP DWG. NO. 79-16

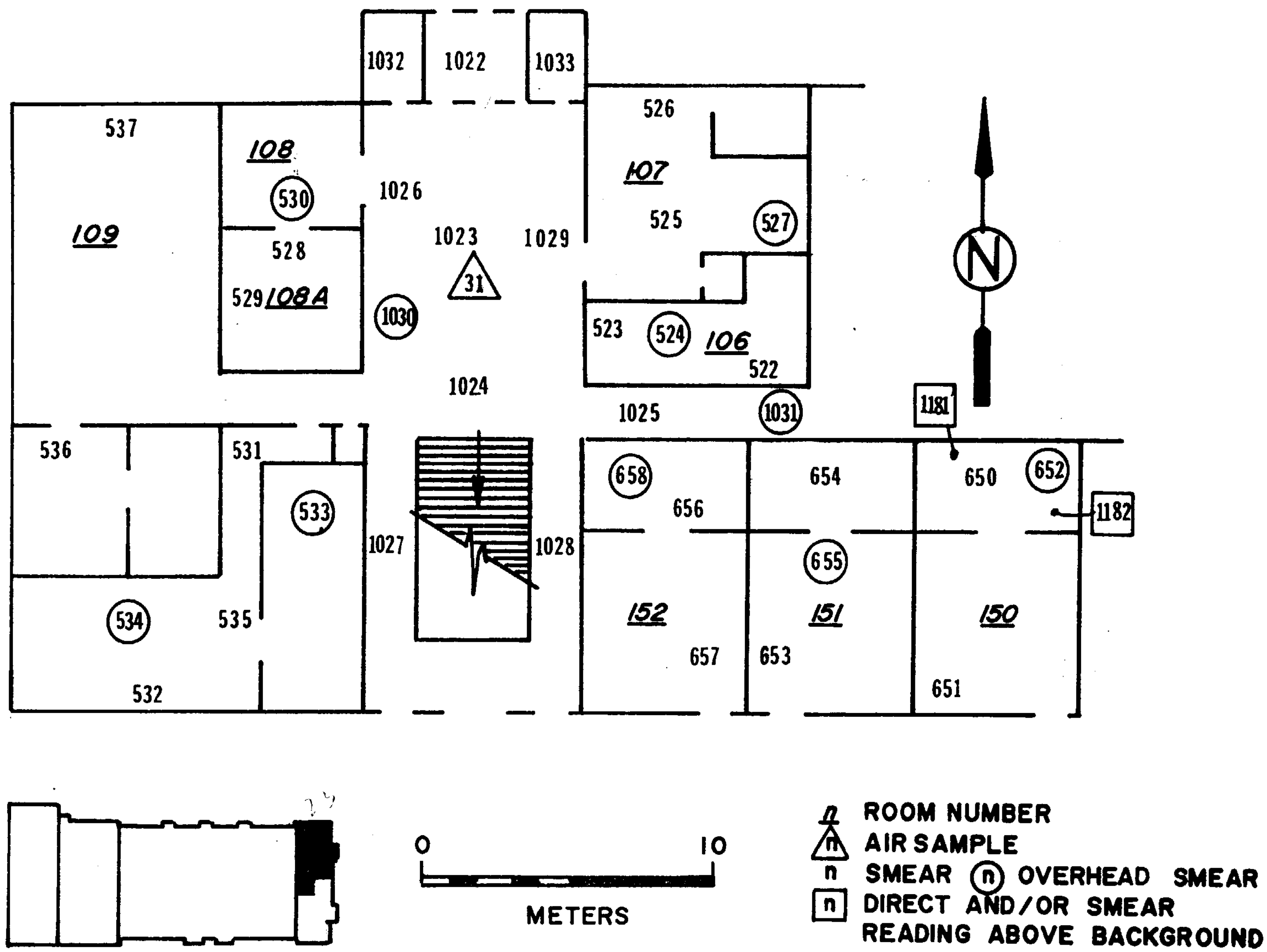


FIGURE 9

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 110, 111, 112, 113, 114, 115, 116 and 117

ANL-HP DWG. NO. 79-23

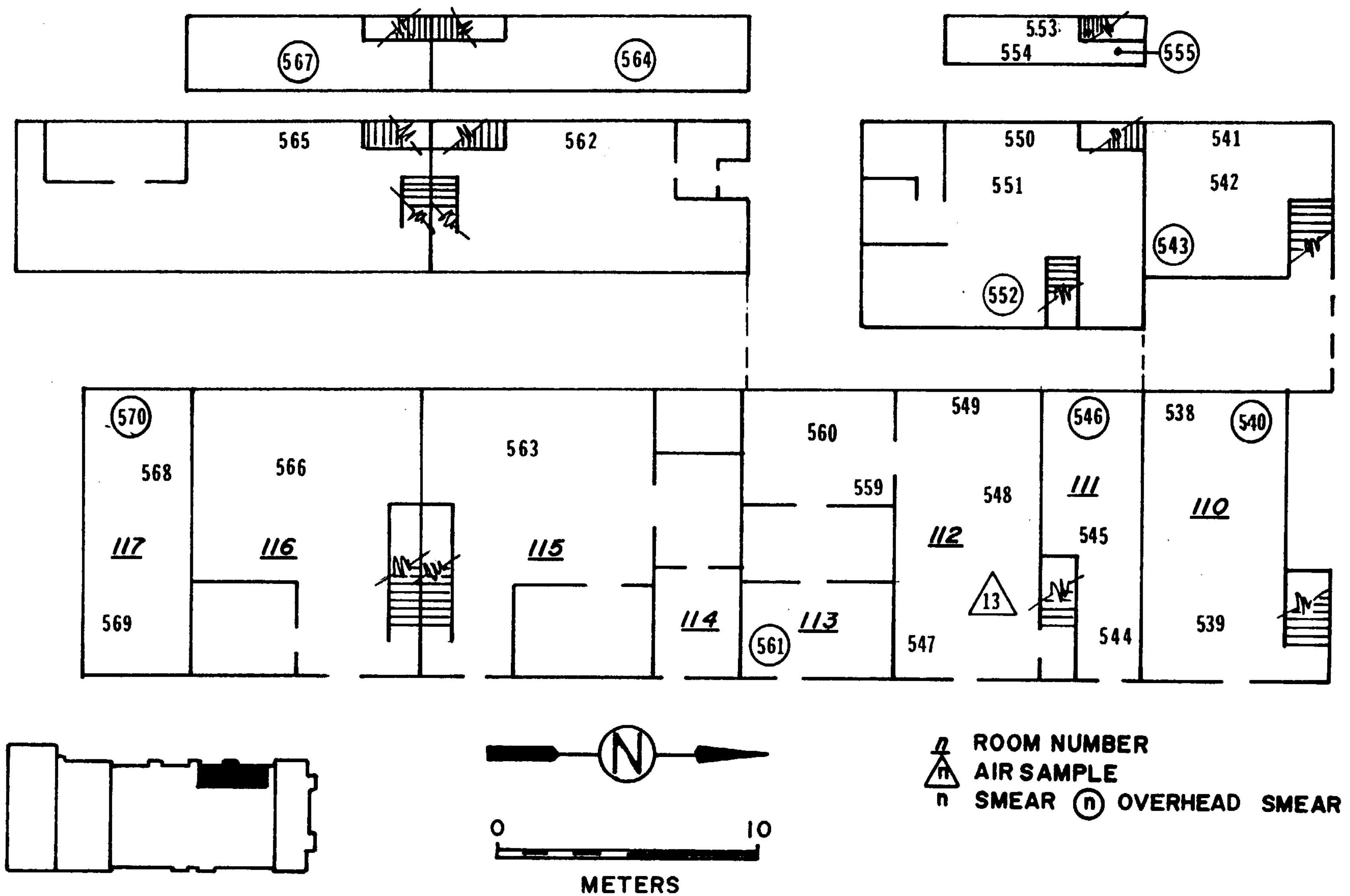


FIGURE 10

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 118, 118A, 119, 120, 121, 122, 123 and 125

ANL-HP DWG. NO. 79-24

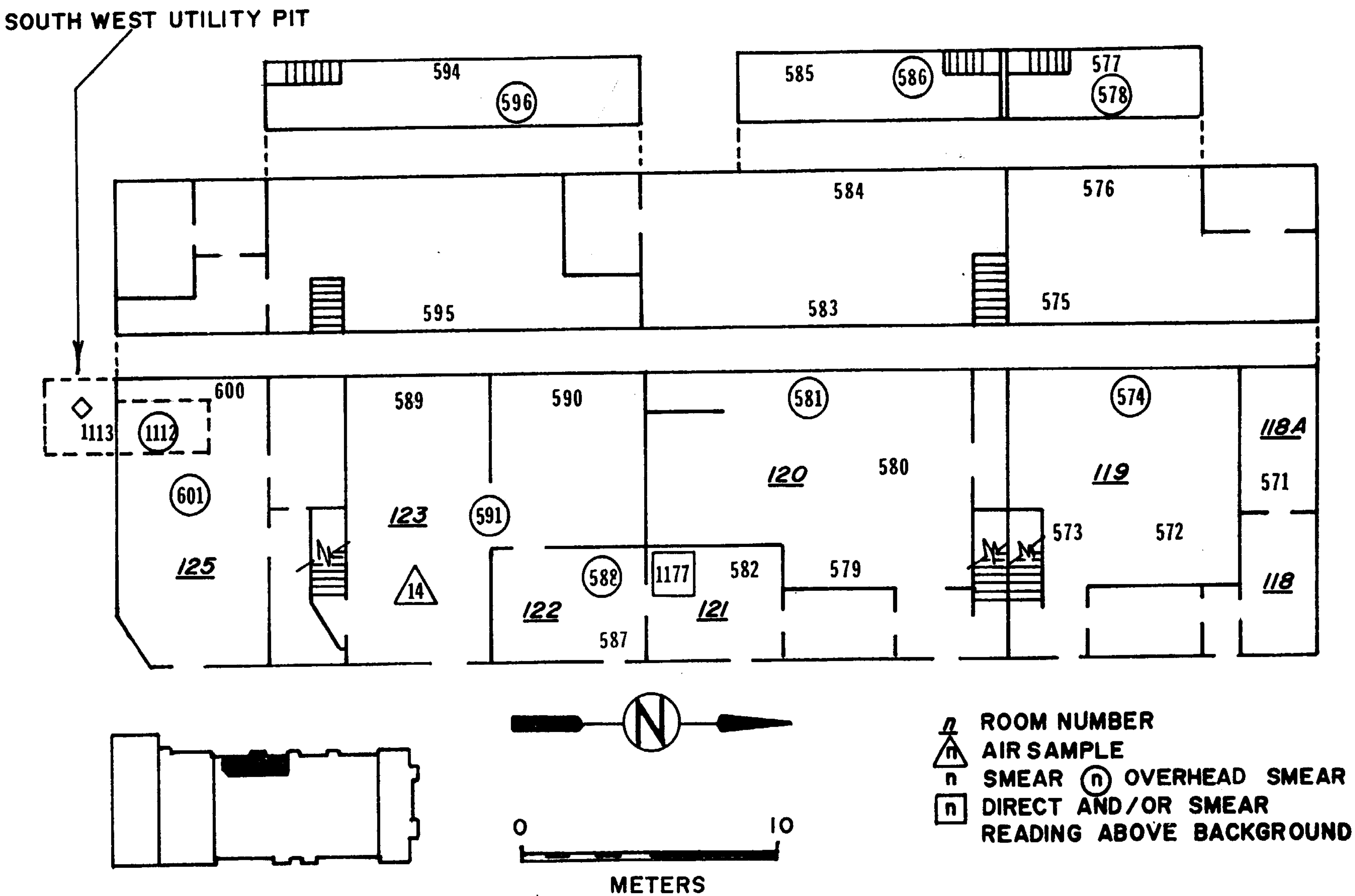


FIGURE 11

SURVEY LOCATIONS IN ROOMS 136, 136A, 136B, 137, 139, 140, 141 and 240

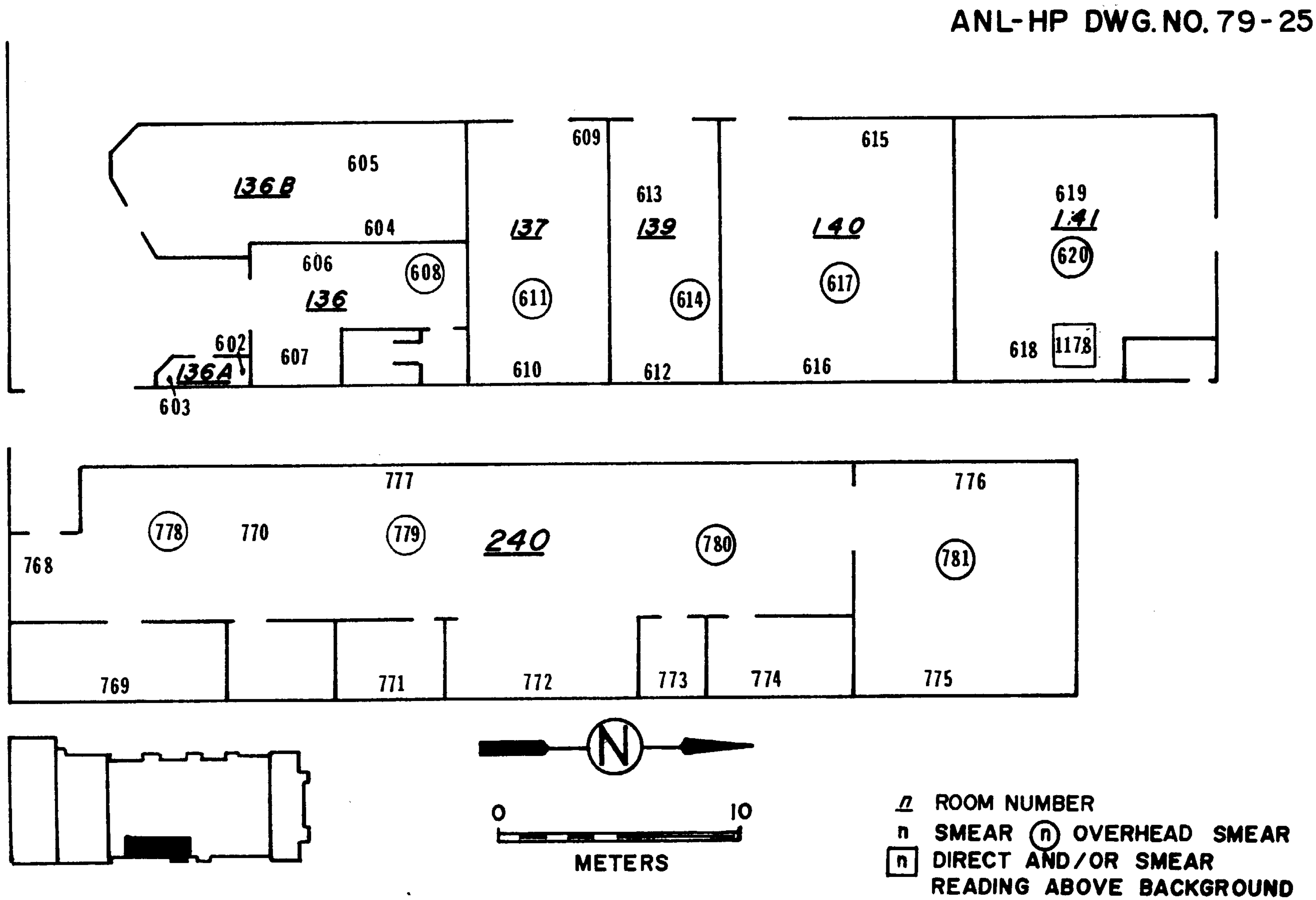


FIGURE 12

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 142, 143, 144, 145, 146, 176, 178, 180 and 273

ANL-HP DWG. NO. 79-26

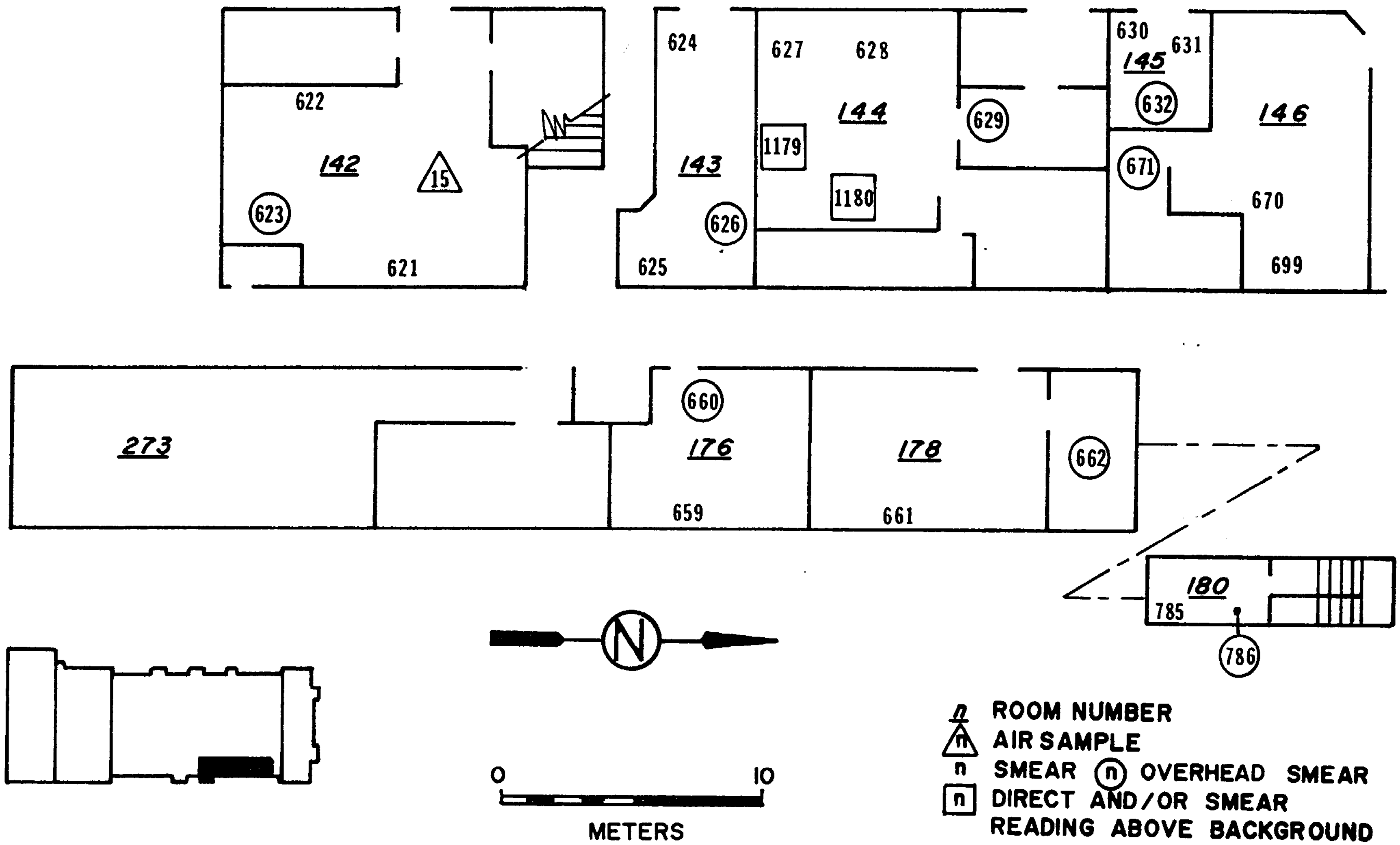


FIGURE 13

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 201A, 202, 203, 204, 205, 206, 207, 208, 210, 211, 212, 212A, 213, 214, 215, 232, 233, 234 and NORTH BALCONY

ANL-HP DWG. NO. 79-17

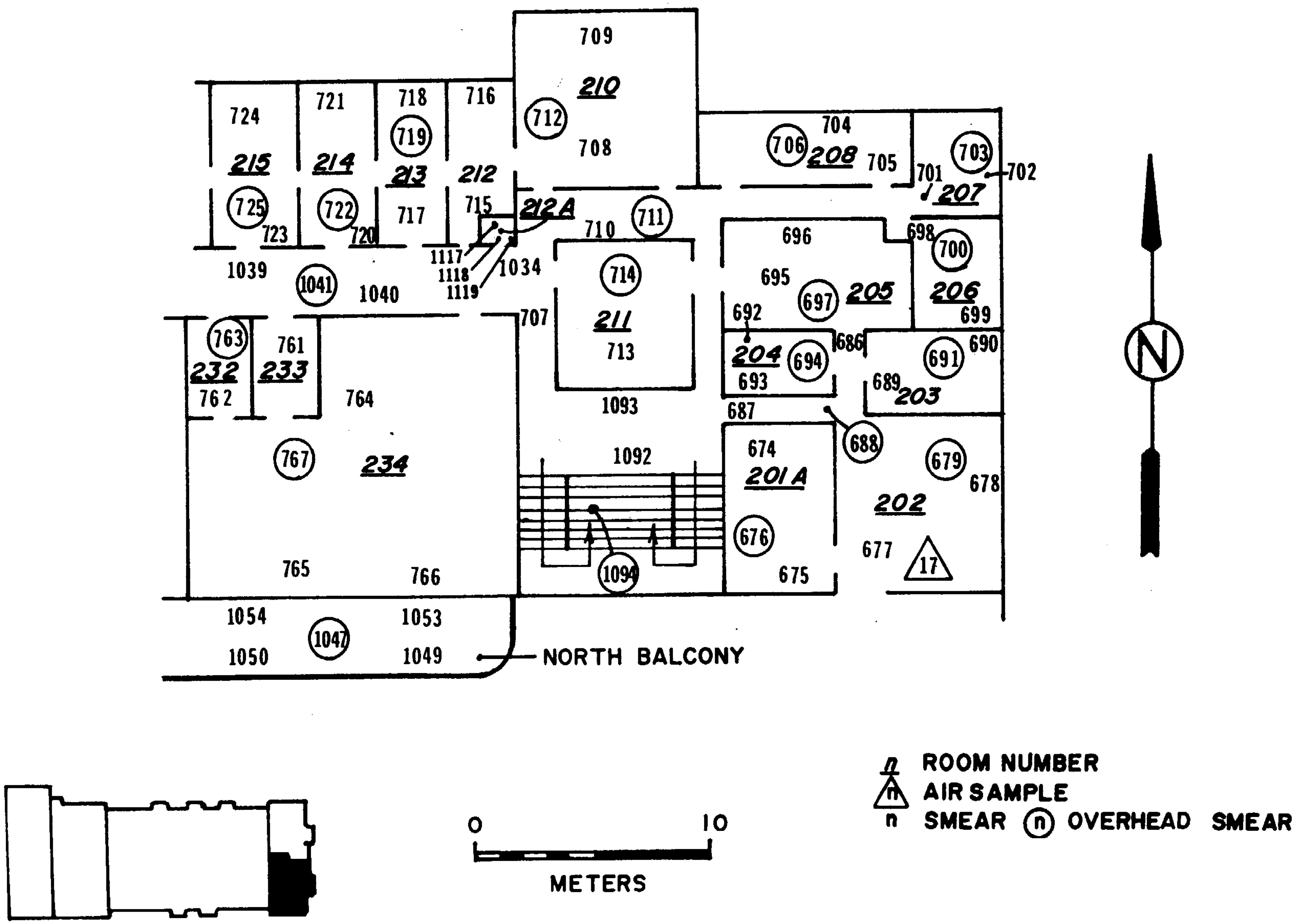


FIGURE 14

SURVEY LOCATIONS IN ROOMS 202A and 202B

ANL-HP DWG. NO. 79-18

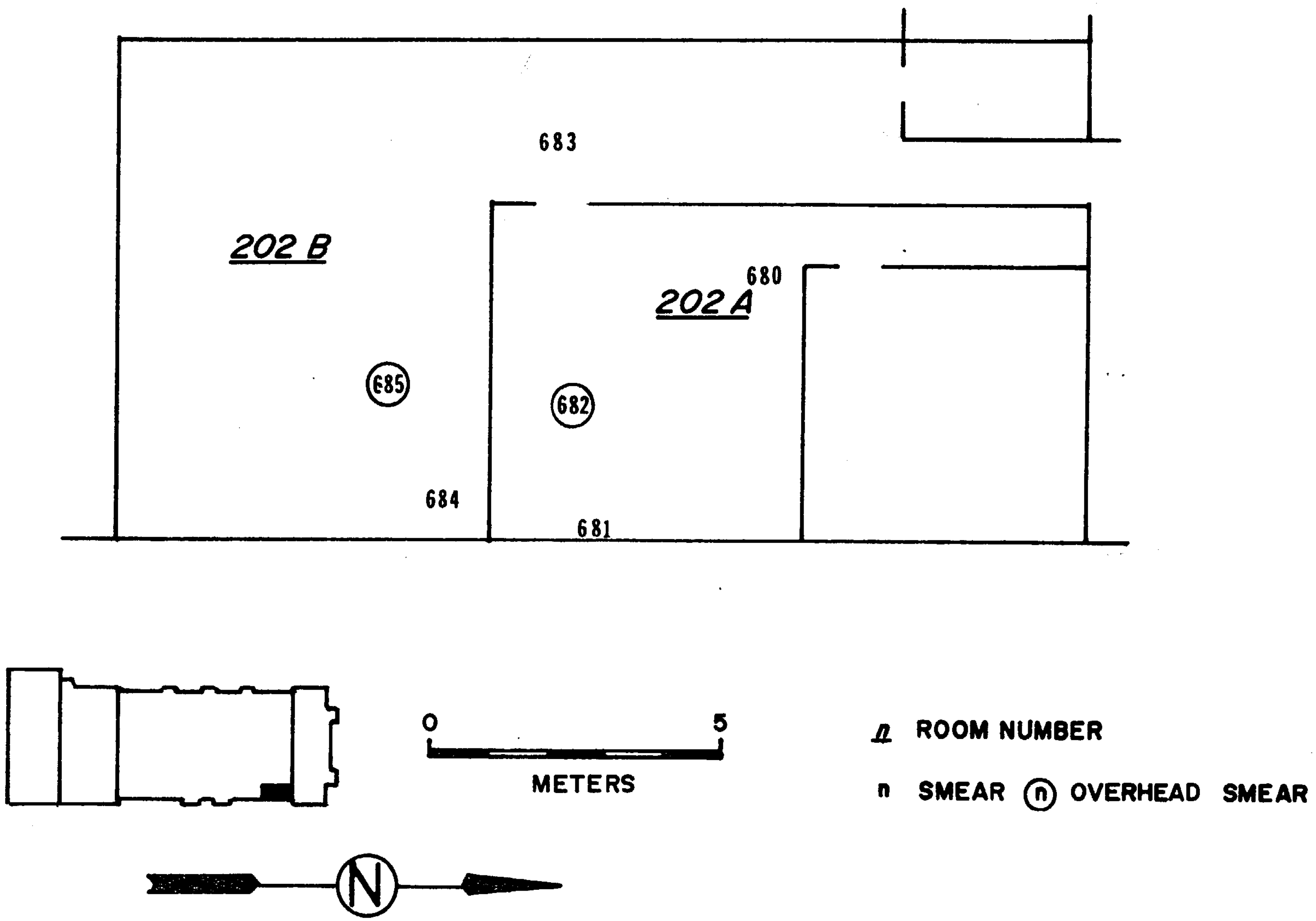


FIGURE 15

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 216, 217, 218, 220, 221, 221A, 223, 224, 225, 225A, 225B, 225C, 230, 231, 231A and NORTH BALCONY

ANL-HP DWG. NO. 79-19

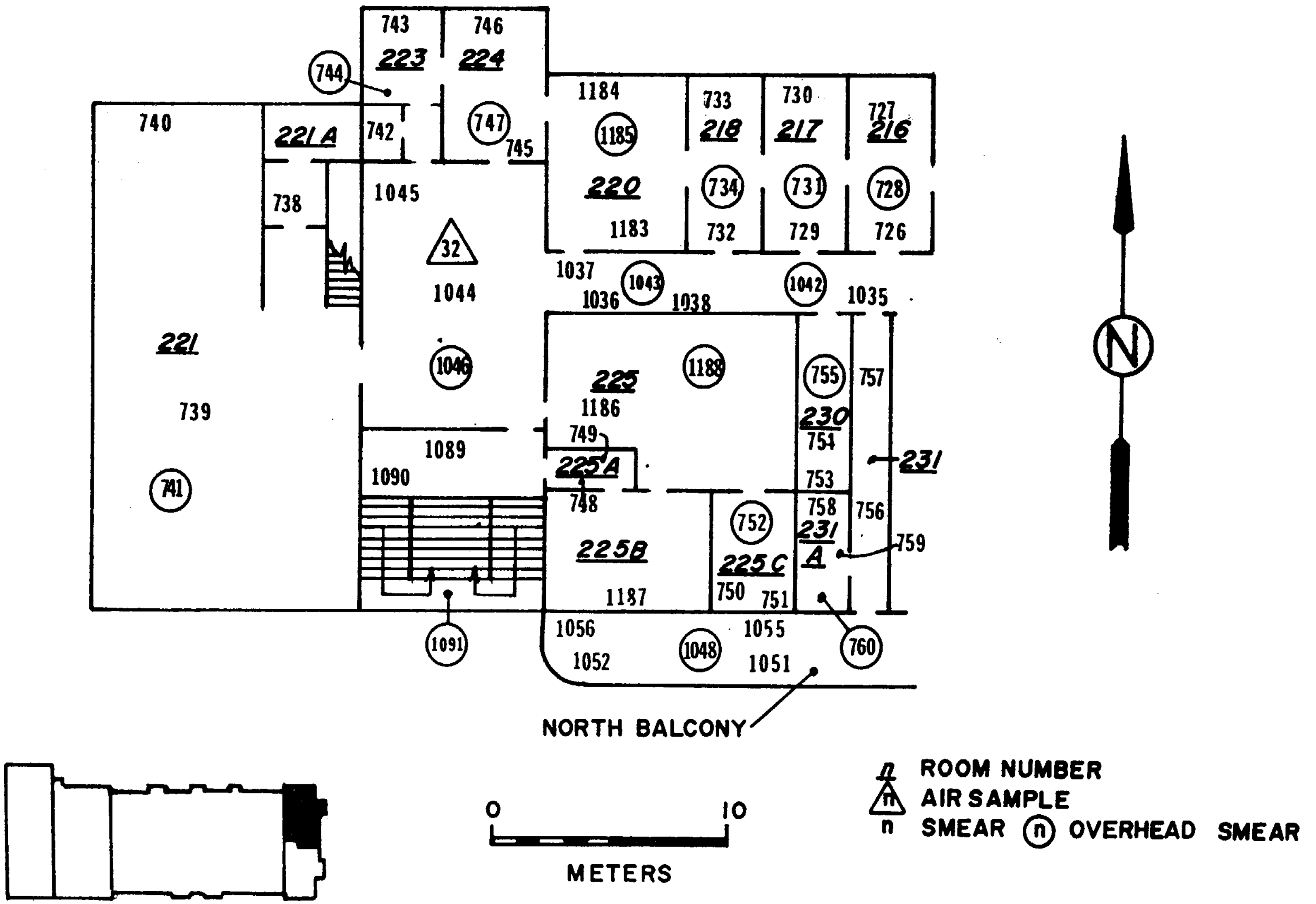


FIGURE 16

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 244, 245, 258, 260, 299 and 299A

ANL-HP DWG. NO. 79-22

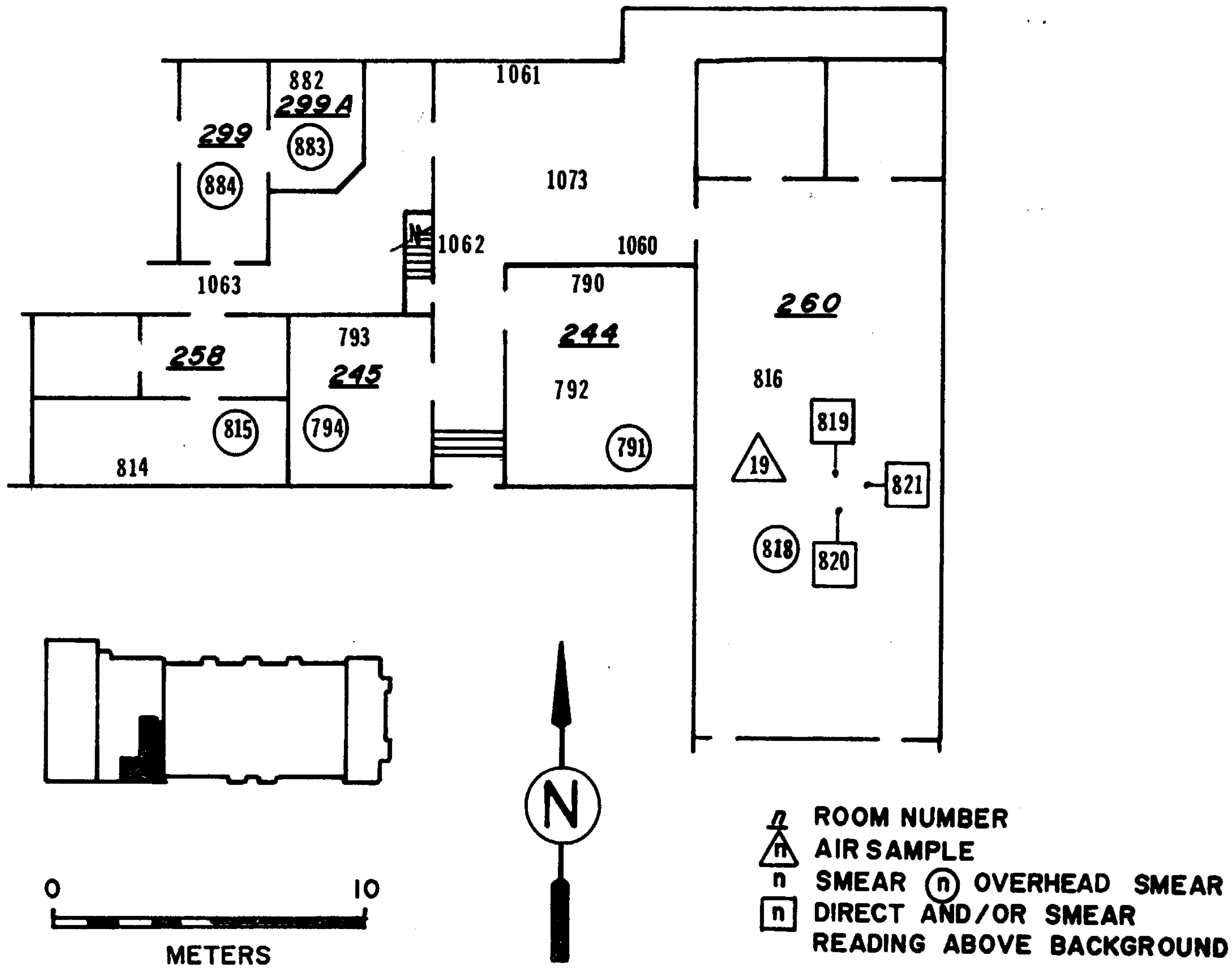


FIGURE 17

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 246, 246A and 246B

ANL-HP DWG. NO. 79-34

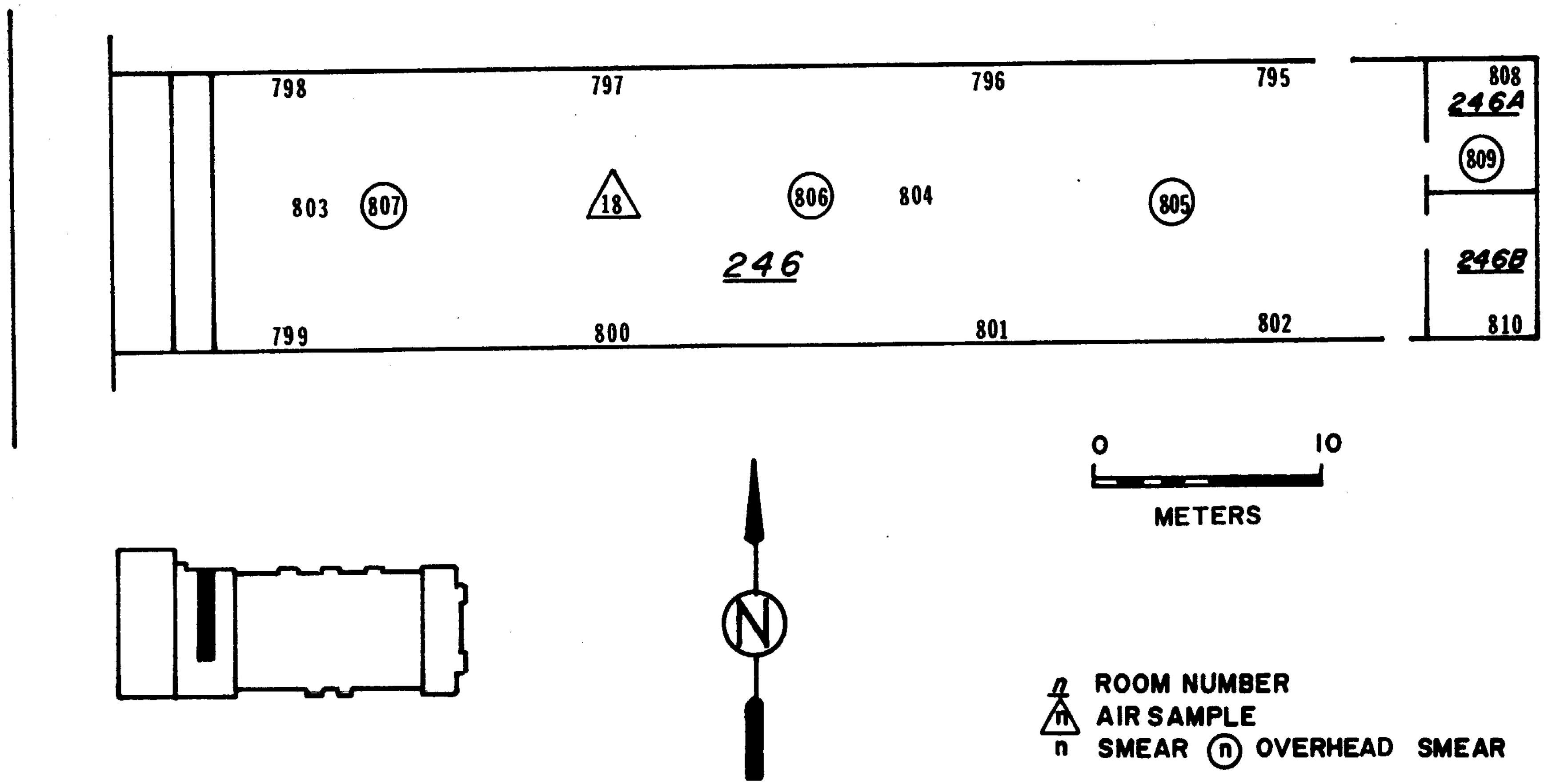


FIGURE 18

SURVEY LOCATIONS IN ROOMS 261, 262, 263, 265, 266, 267, 269, 270 and 271

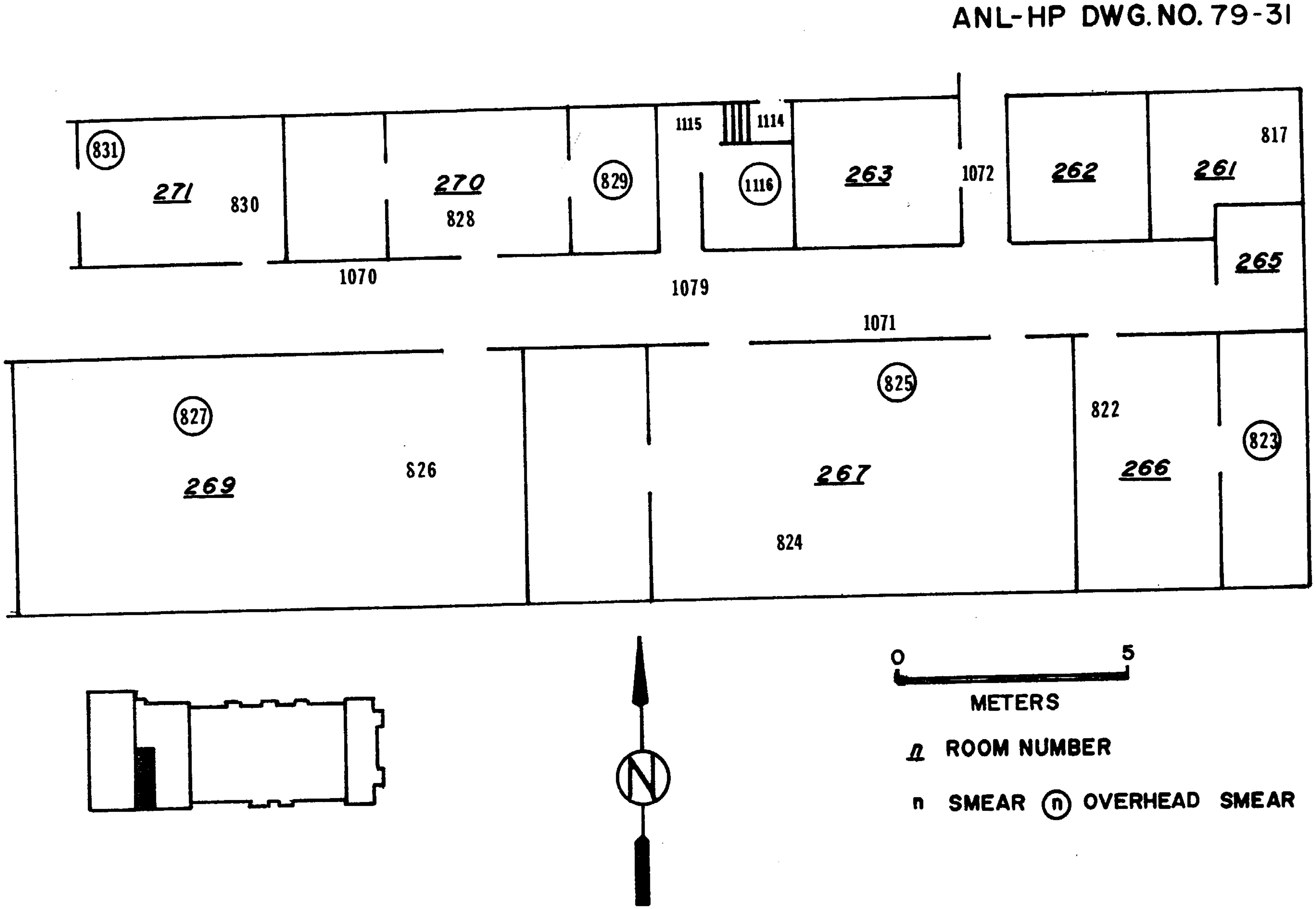


FIGURE 19

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 272, 274, 275, 277, 278, 279, 280, 281, 282, 283 and 284

ANL-HP DWG. NO. 79-33

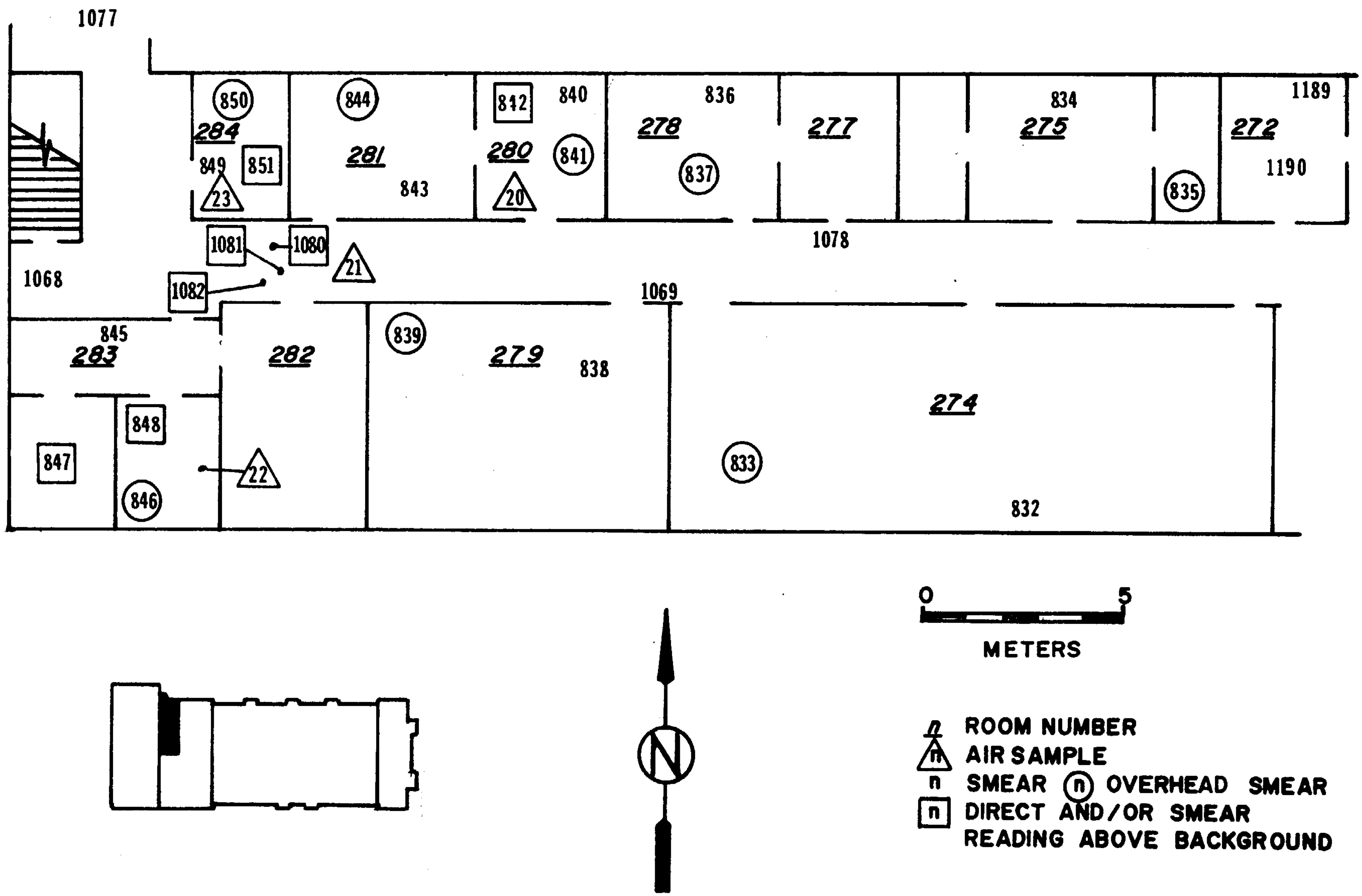


FIGURE 20

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 242, 285, 286, 287, 288, 289, 290, 291, 292
293, 294, 295, 296, 297 and 298

ANL-HP DWG.NO. 79-32

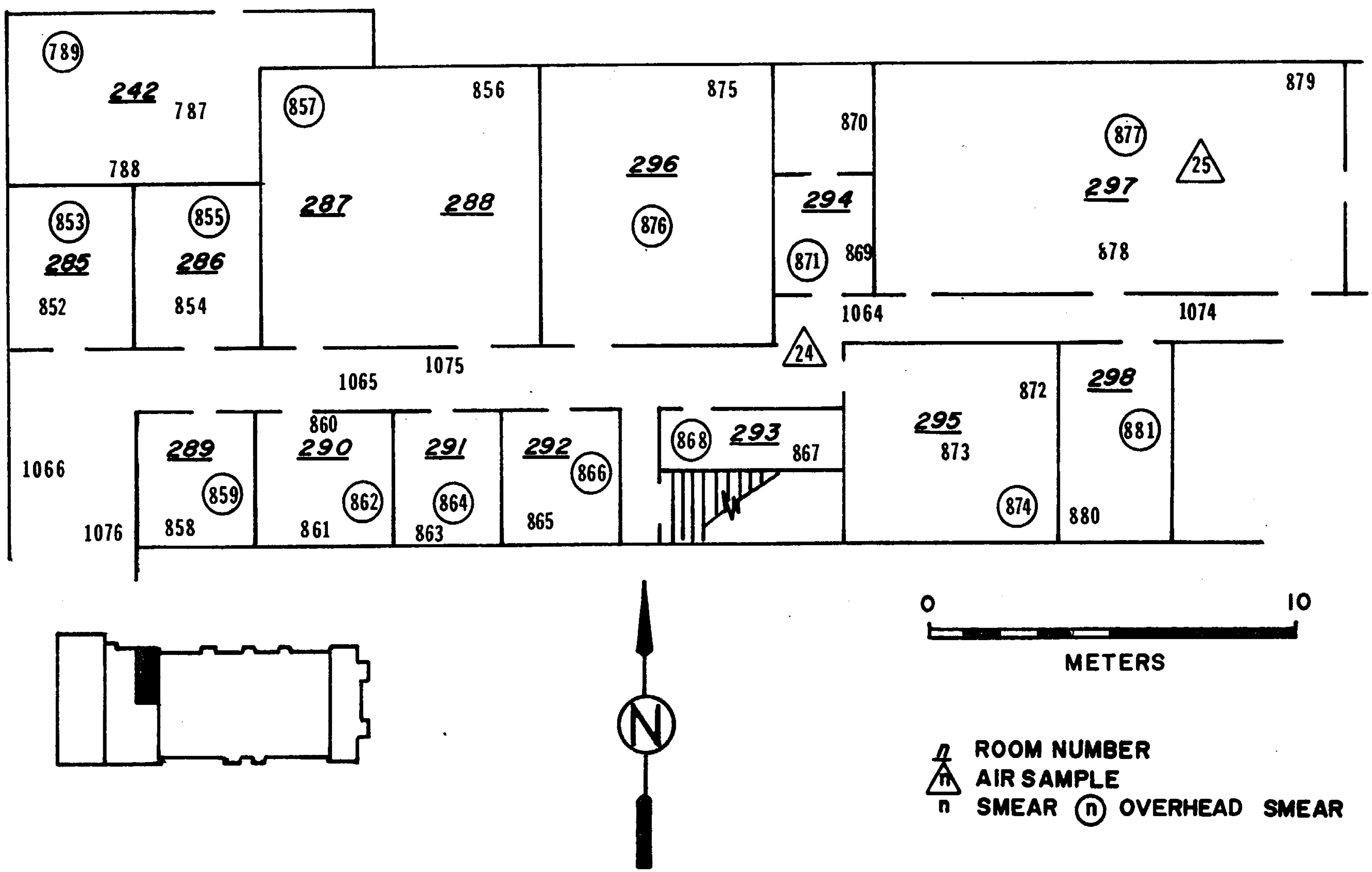
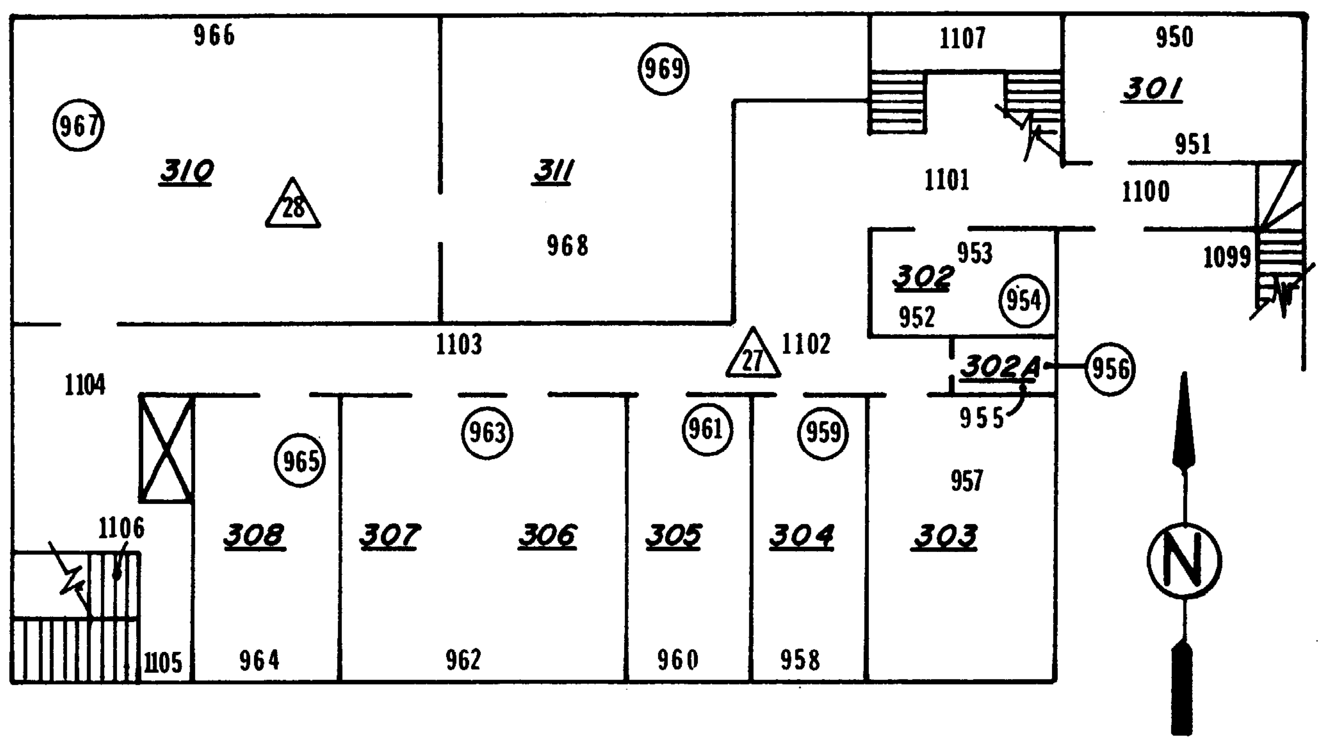


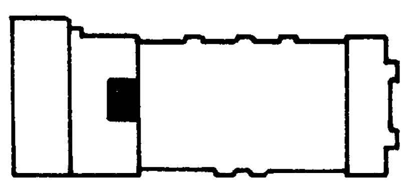
FIGURE 21

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 301, 302, 302A, 303, 304, 305, 306, 307, 308, 310 and 311

SOUTH END

ANL-HP DWG. NO. 79-27





n ROOM NUMBER
n AIR SAMPLE
n SMEAR (n) OVERHEAD SMEAR

FIGURE 22

AIR SAMPLE AND SURVEY LOCATIONS IN ROOMS 301, 302, 303, 304, 305, 306, 307, 308, 309, 316 and 317

NORTH END

ANL-HP DWG. NO. 79-20

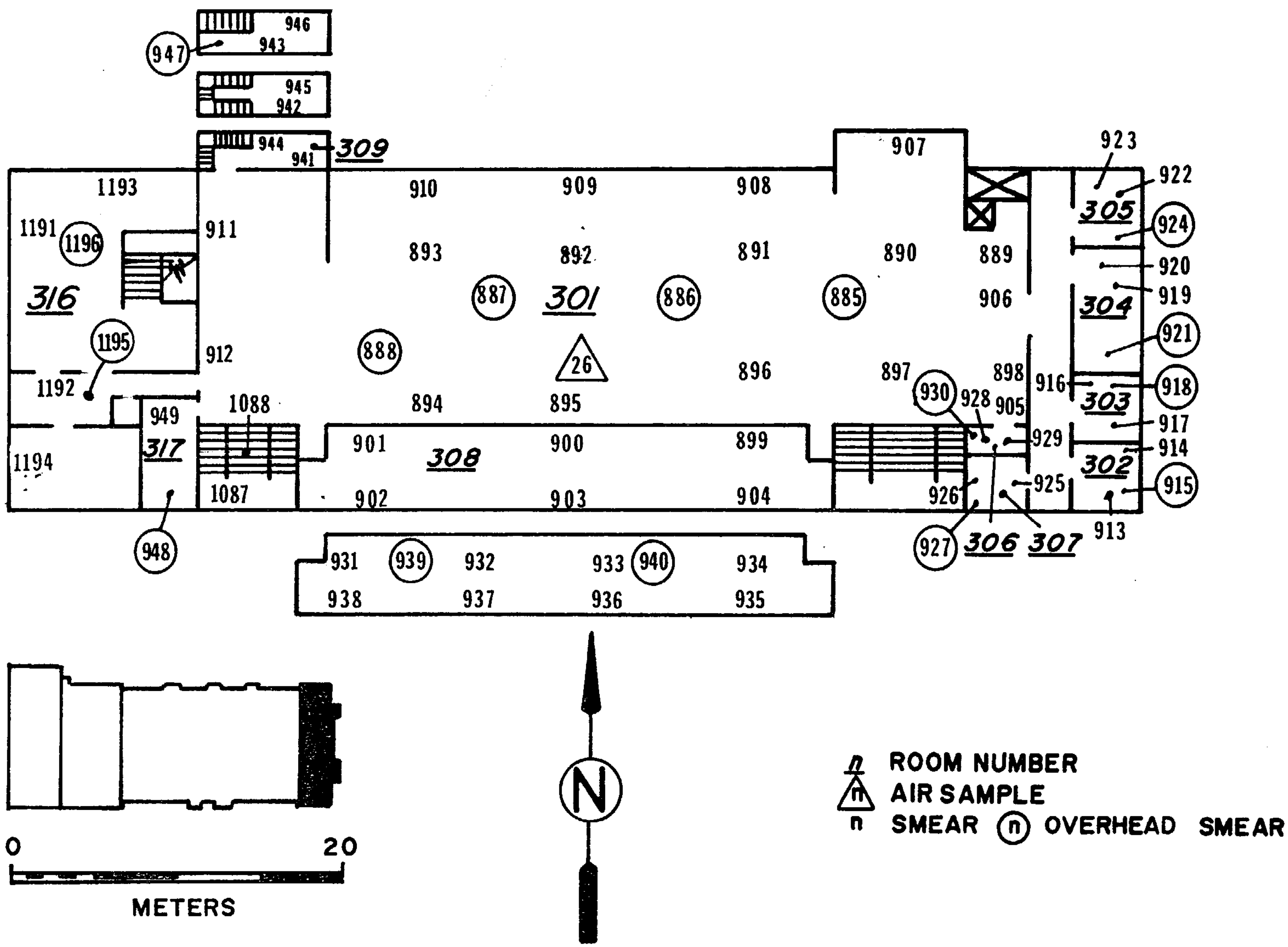


FIGURE 23

AIR SAMPLE AND SURVEY LOCATIONS IN ROOM 401

SOUTH END

ANL-HP DWG. NO. 79-28

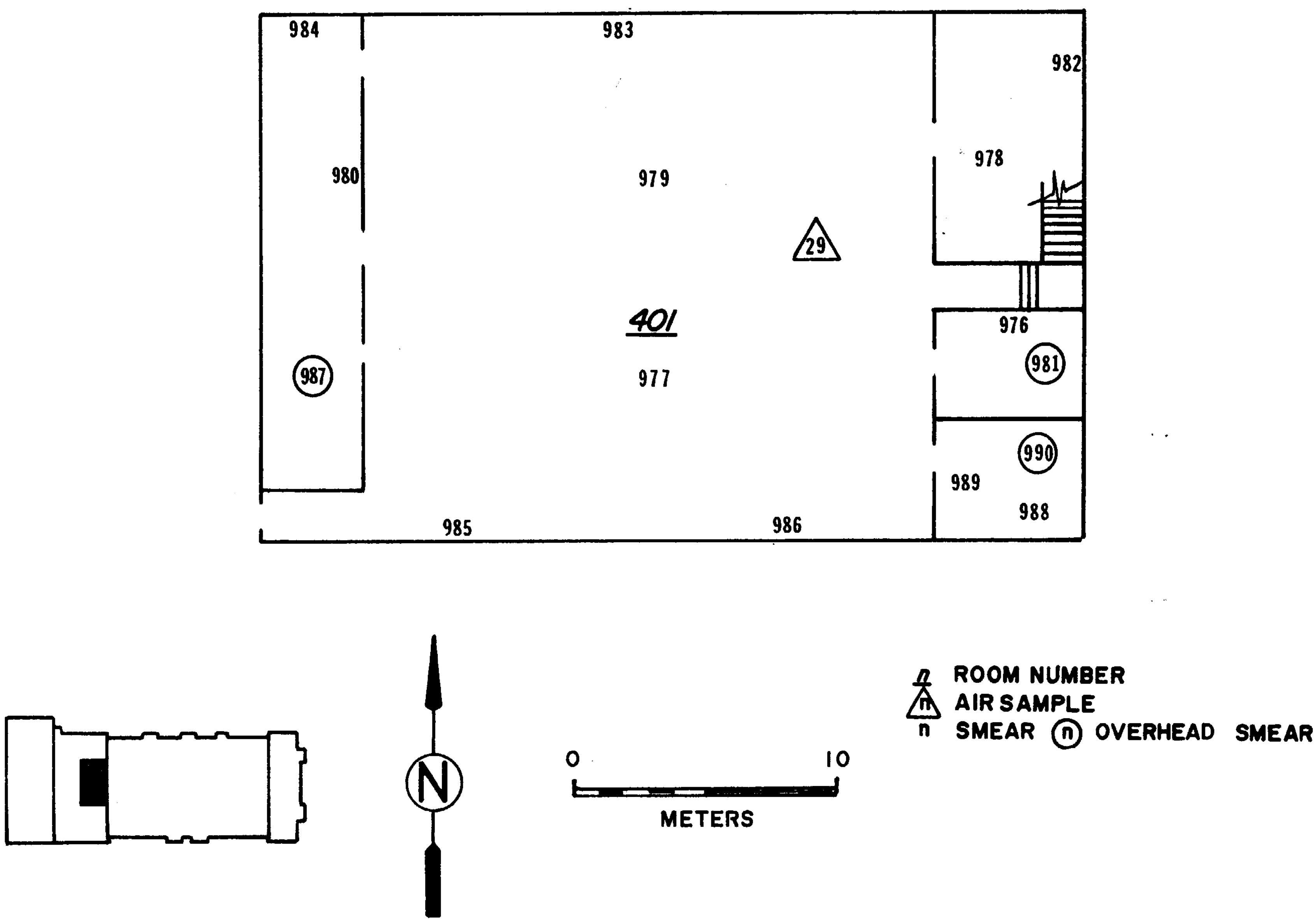


FIGURE 24

AIR SAMPLE AND SURVEY LOCATIONS ON SERVICE FLOOR

ANL-HP DWG. NO. 79-21

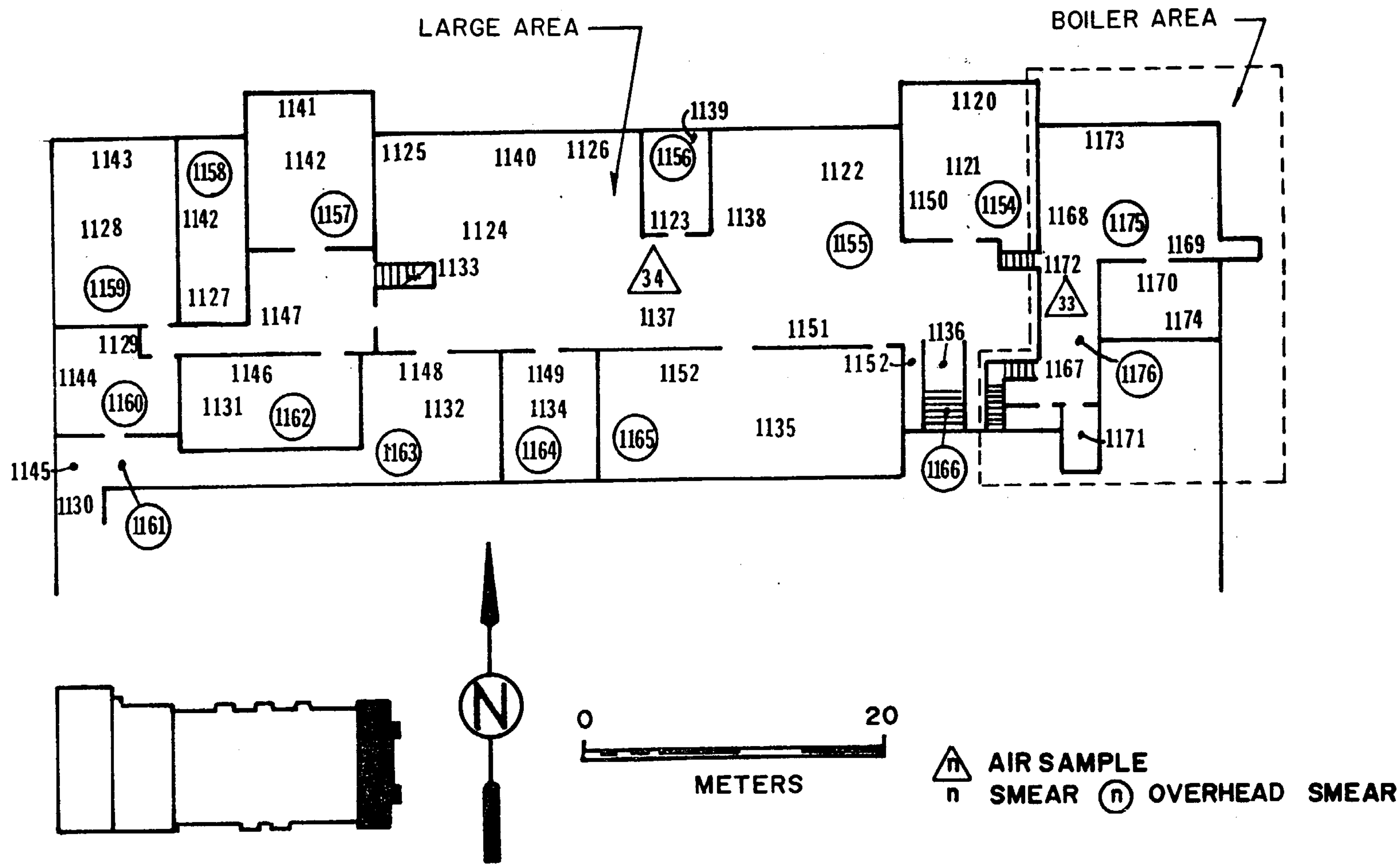


FIGURE 25

SURVEY LOCATIONS - ROOF OF ROOM 2

ANL-HP DWG. NO. 79-30

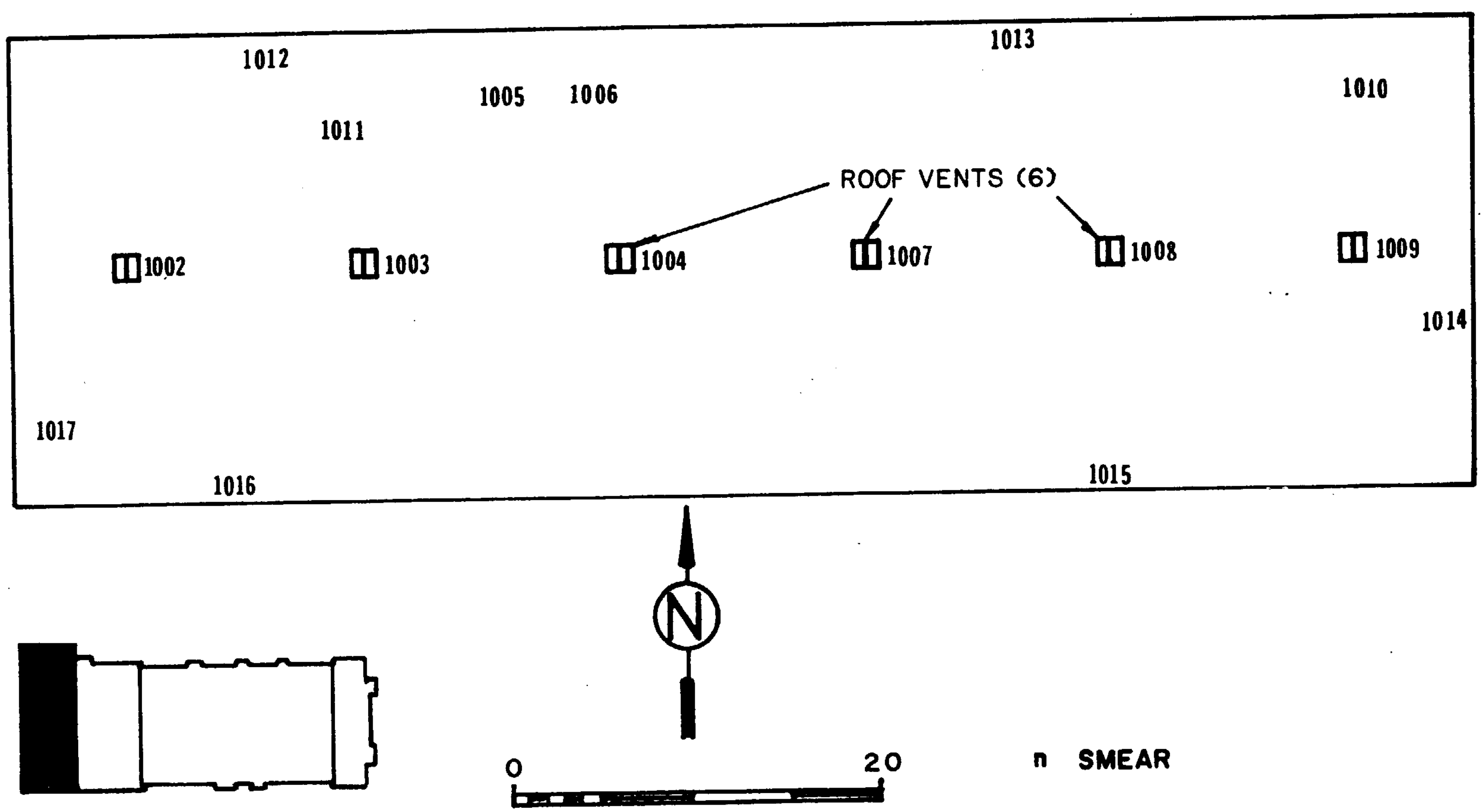


FIGURE 26

SURVEY LOCATIONS - ROOF OF ROOMS 1, 5 and 6

ANL-HP DWG. NO. 79 - 29

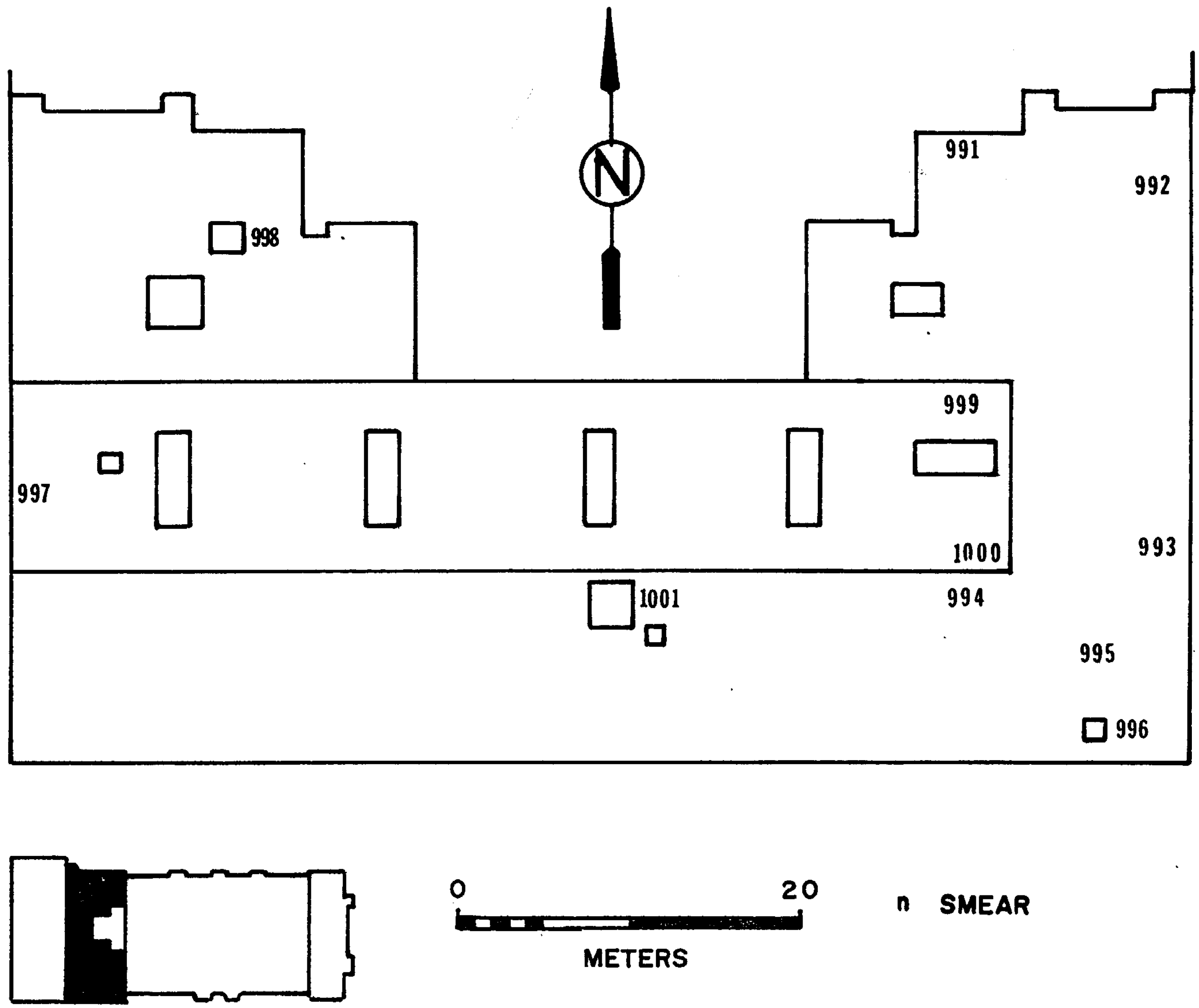


FIGURE 27

DRAINAGE SYSTEM FOR ROOM 1 AND 5 FLOORS

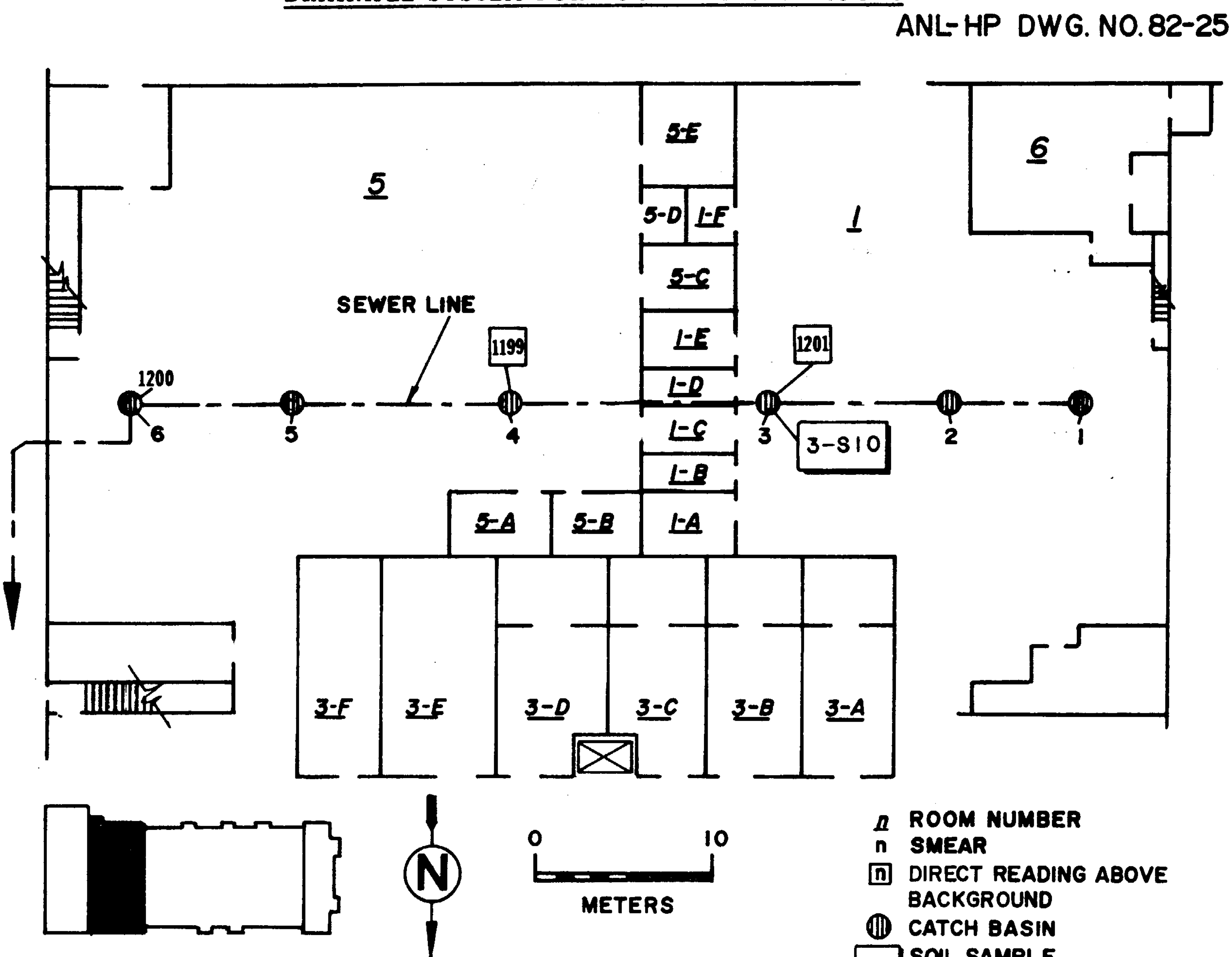


FIGURE 28

ILLINOIS NATIONAL GUARD ARMORY ENVIROMENTAL SOIL SAMPLE LOCATIONS

ANL-HP DWG. NO. 79-4

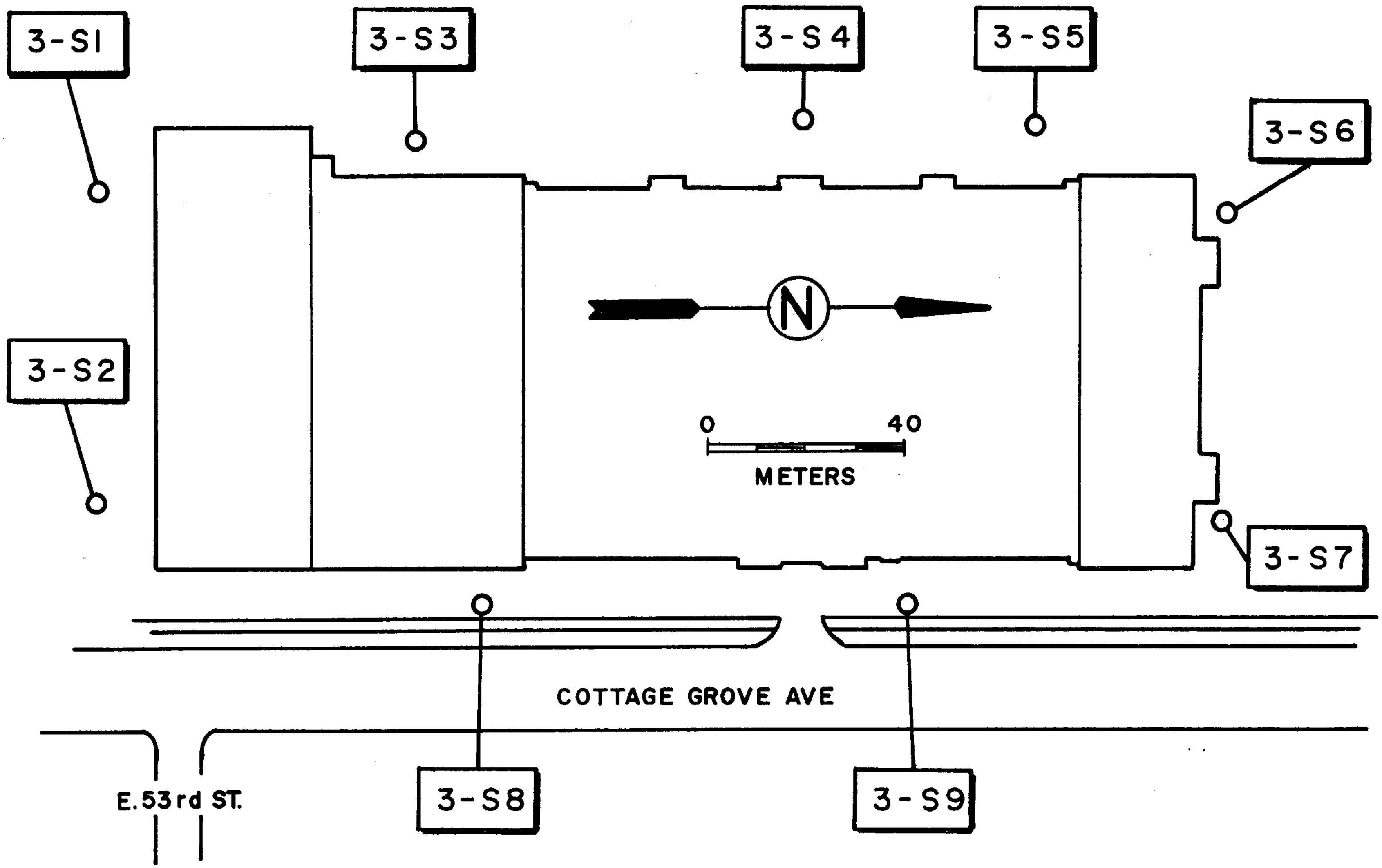


FIGURE 29

DIAGRAM OF BALLOON SMEAR APPARATUS

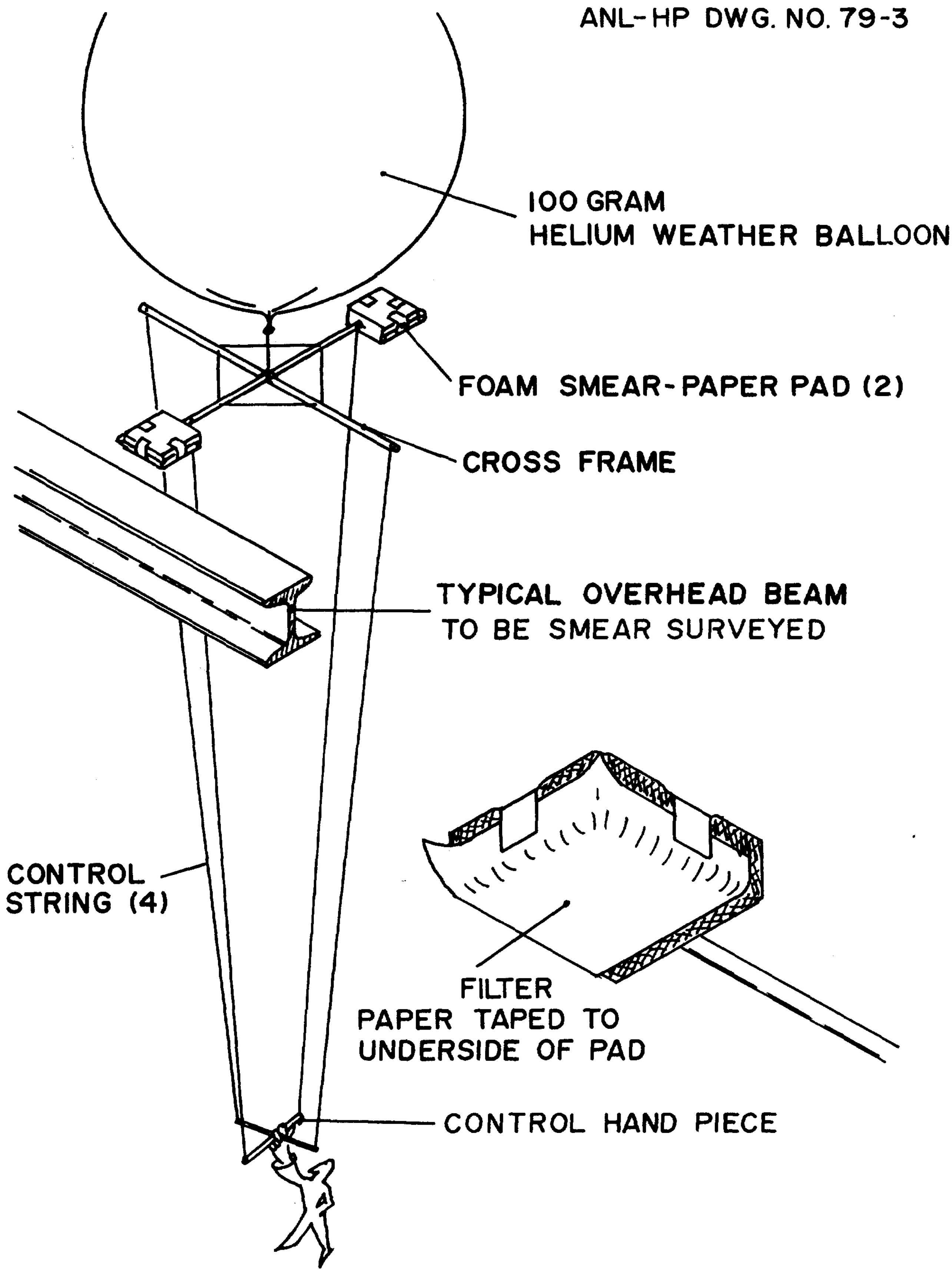
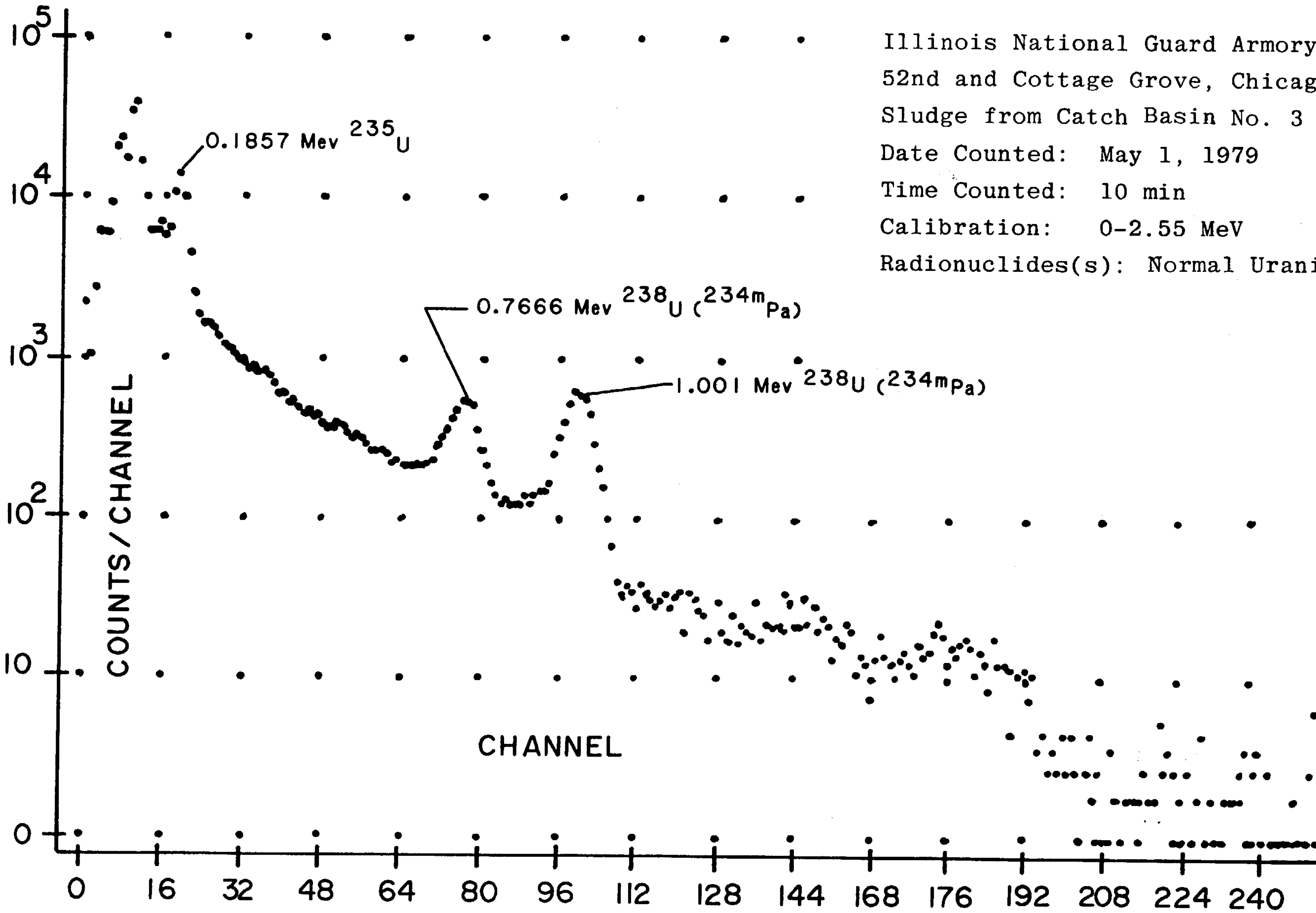


FIGURE 30

GAMMA SPECTRUM ANALYSIS OF SLUDGE



Illinois National Guard Armory
52nd and Cottage Grove, Chicago, IL
Sludge from Catch Basin No. 3
Date Counted: May 1, 1979
Time Counted: 10 min
Calibration: 0-2.55 MeV
Radionuclides(s): Normal Uranium

FIGURE 31

SOIL-SAMPLING PROCEDURE AND PROCESSING DIAGRAM

ANL-HP-DWG. 78-2

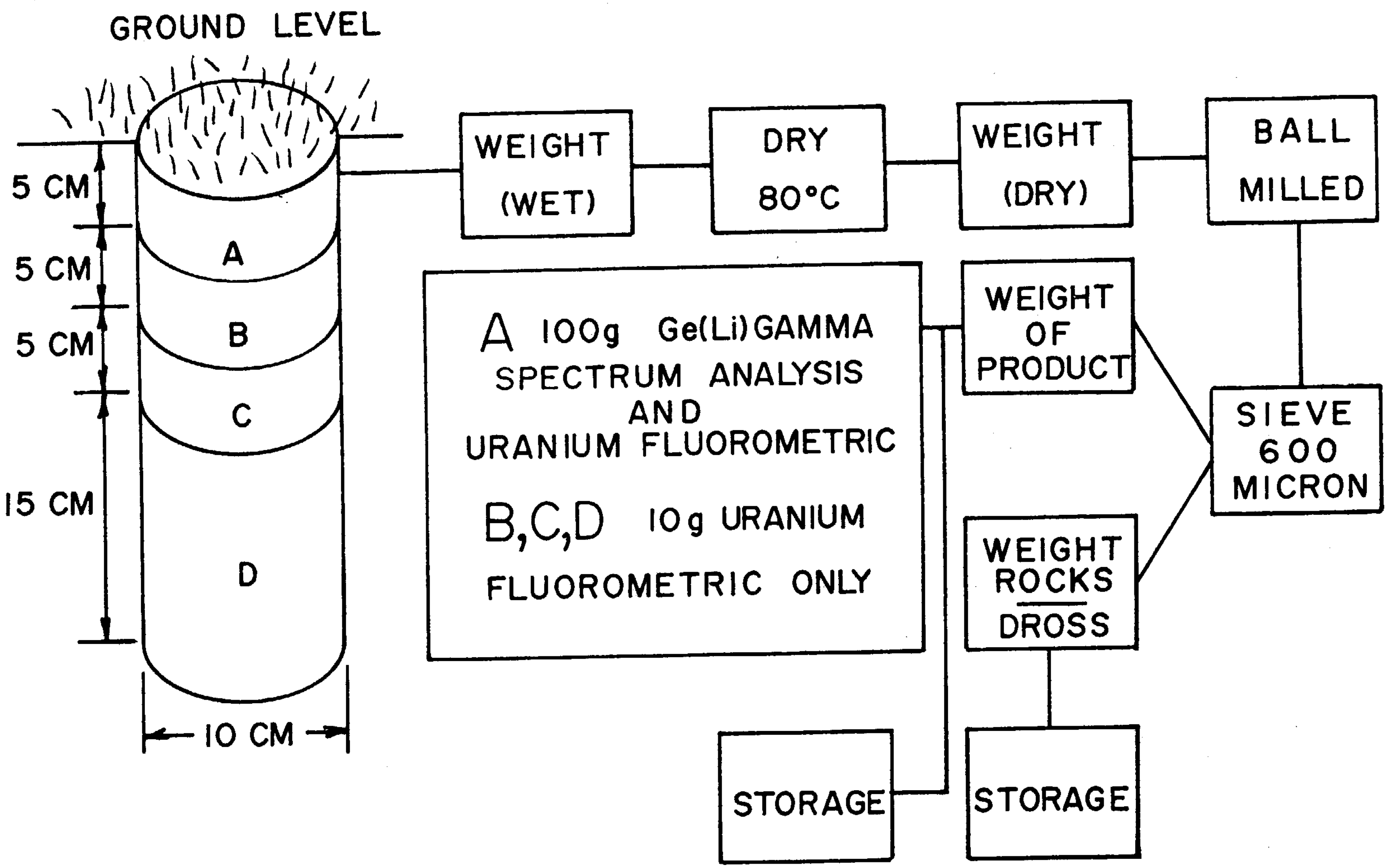


TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey: Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2): Beta	Alpha	End Window (mR/h): Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
1	100	95	0.0006						Air Sample 1
				2.1×10^4	BKGD[c]	0.3	BKGD	BKGD	Location 97, Spot on concrete floor
				2.0×10^4	BKGD	2.0	BKGD	BKGD	Location 98, Spot on concrete floor
				1.0×10^4	BKGD	0.1	BKGD	BKGD	Location 99, Spot on concrete floor
				1.2×10^4	3.7×10^2	0.1	BKGD	BKGD	Location 100, Spot on concrete floor
				3.4×10^4	BKGD	0.1	BKGD	BKGD	Location 101, Spot on concrete floor
				1.6×10^4	BKGD	BKGD	BKGD	BKGD	Location 102, Spot on concrete floor
				2.0×10^4	BKGD	BKGD	BKGD	BKGD	Location 103, Spot on concrete floor
				3.4×10^5	BKGD	3.0	BKGD	a =470[e] $\beta\gamma = 1.3 \times 10^3$	Location 104, Spot on cast iron manhole cover of Catch Basin 3
				2.3×10^4	BKGD	0.12	BKGD	BKGD	Location 105, Spot on concrete pillar
				3.4×10^2	2.9×10^3	NRR[g]	NRR	$\alpha = 43$ $\beta\gamma = 110$	Location 106, Spot on concrete overhead

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm²)	Comments
1 (cont'd)				2.0×10^4	BKGD[c]	0.2	BKGD	BKGD	Location 107, Spot on concrete floor
				3.4×10^2	2.3×10^3	BKGD	BKGD	α =15[e] βγ=31	Location 108, Spot on concrete overhead
				BKGD	NA[d]	NA	NA	α =BKGD βγ=20	Location 109, Spot on concrete overhead
				BKGD	NA	NA	NA	α =BKGD βγ=46	Location 110, Spot on concrete overhead
				BKGD	NA	NA	NA	α =BKGD βγ=20	Location 111, Spot on concrete overhead
				BKGD	NA	NA	NA	α =BKGD βγ=20	Location 112, Spot on concrete overhead
				BKGD	NA	NA	NA	α =BKGD βγ=27	Location 113, Spot on concrete overhead
				BKGD	NA	NA	NA	α =BKGD βγ=24	Location 114, Spot on concrete overhead
				BKGD	NA	NA	NA	α =18 βγ=BKGD	Location 115, Spot on concrete overhead
				BKGD	NA	NA	NA	α =7 βγ=BKGD	Location 116, Spot on concrete overhead
				BKGD	NA	NA	NA	α =20 βγ=63	Location 117, Spot on concrete overhead

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm²)	Comments
1 (cont'd)				6.7×10^4	5.8×10^4	0.1	BKGD[c]	$\alpha = 1.7 \times 10^3$[e] $\beta\gamma = 2.5 \times 10^3$	Location 121, Spot on concrete overhead
				BKGD	NA[d]	NA	NA	α =BKGD $\beta\gamma = 15$	Location 122, Spot on concrete overhead
				BKGD	NA	NA	NA	α =BKGD $\beta\gamma = 32$	Location 123, Spot on concrete overhead
				1.5×10^4	2.9×10^4	BKGD	BKGD	$\alpha = 500$ $\beta\gamma = 760$	Location 126, Spot on concrete overhead
				3.1×10^4	6.9×10^3	BKGD	BKGD	$\alpha = 175$ $\beta\gamma = 140$	Location 127, Spot on concrete overhead
				6.3×10^4	6.9×10^3	BKGD	BKGD	$\alpha = 170$ $\beta\gamma = 140$	Location 128, Spot on concrete overhead
				6.3×10^4	6.9×10^3	NRR[g]	NRR	$\alpha = 33$ $\beta\gamma = 59$	Location 129, Spot on concrete overhead (vertical beam)
				1.5×10^5	2.9×10^4	0.2	BKGD	$\alpha = 140$ $\beta\gamma = 250$	Location 131, Spot on concrete overhead
				5.4×10^4	BKGD	NRR	NRR	$\alpha = 510$ $\beta\gamma = 920$	Location 132, Spot on concrete overhead
				1.7×10^5	5.8×10^4	0.5	BKGD	$\alpha = 710$ $\beta\gamma = 1.2 \times 10^3$	Location 133, Spot on concrete overhead

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey: Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2): Beta	Alpha	End Window (mR/h): Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
1 (cont'd)				2.6×10^4	1.2×10^4	BKGD[c]	BKGD	$\alpha = 90$[e] $\beta\gamma = 95$	Location 134, Spot on concrete overhead
				1.6×10^4	BKGD	BKGD	BKGD	$\alpha = 210$ $\beta\gamma = 170$	Location 135, Spot on concrete overhead
				2.3×10^4	1.7×10^4	BKGD	BKGD	$\alpha = 92$ $\beta\gamma = 140$	Location 136, Spot on concrete overhead
				5.7×10^4	1.7×10^4	0.1	BKGD	$\alpha = 84$ $\beta\gamma = 170$	Location 137, Spot on concrete overhead
				1.5×10^5	3.5×10^4	0.1	BKGD	$\alpha = 830$ $\beta\gamma = 1.0 \times 10^3$	Location 138, Spot on concrete overhead
				1.4×10^5	5.8×10^4	0.5	BKGD	$\alpha = 800$ $\beta\gamma = 1.2 \times 10^3$	Location 139, Spot on concrete overhead
				1.7×10^3	BKGD	BKGD	BKGD	$\alpha = 28$ $\beta\gamma = 37$	Location 140, Spot on concrete overhead
				3.4×10^2	BKGD	BKGD	BKGD	$\alpha = 10$ $\beta\gamma = 38$	Location 141, Spot on concrete overhead
				3.4×10^2	BKGD	BKGD	BKGD	$\alpha = 21$ $\beta\gamma = 29$	Location 142, Spot on concrete overhead
				3.4×10^2	BKGD	BKGD	BKGD	$\alpha = 8$ $\beta\gamma$=BKGD	Location 143, Spot on concrete overhead
				6.9×10^2	BKGD	BKGD	BKGD	$\alpha = 10$ $\beta\gamma$=BKGD	Location 144, Spot on concrete overhead

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey: Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2): Beta	Alpha	End Window (mR/h): Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
1 (cont'd)				BKGD[c]	BKGD	NA[d]	NA	α =BKGD[e] βγ=20	Location 145, Spot on concrete overhead
				9.3×10^{3}	BKGD	BKGD	BKGD	α =23 βγ=41	Location 146, Spot on concrete overhead
				1.1×10^{4}	2.3×10^{3}	BKGD	BKGD	α =25 βγ=28	Location 147, Spot on concrete overhead
				3.4×10^{2}	BKGD	NRR	NRR	α =6 βγ=BKGD	Location 148, Spot on concrete overhead
				BKGD	BKGD	NA	NA	α =12 βγ=36	Location 149, Spot on concrete overhead
				2.4×10^{3}	BKGD	BKGD	BKGD	α =28 βγ=57	Location 150, Spot on concrete overhead
				9.3×10^{3}	BKGD	BKGD	BKGD	α =38 βγ=87	Location 151, Spot on concrete overhead
				1.3×10^{4}	BKGD	BKGD	BKGD	α =49 βγ=55	Location 152, Spot on concrete overhead (in cracks)
				BKGD	BKGD	BKGD	BKGD	α =BKGD βγ=17	Location 153, Spot on concrete overhead
				BKGD	BKGD	BKGD	BKGD	α =BKGD βγ=14	Location 154, Spot on concrete overhead
				1.4×10^{5}	5.8×10^{4}	0.5	BKGD	α =330 βγ=405	Location 155, Spot on concrete overhead

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
1 (cont'd)				1.4×10^{5}	5.8×10^{4}	0.3	BKGD[c]	$\alpha = 1.4 \times 10^{3}$[e] $\beta\gamma = 1.8 \times 10^{3}$	Location 156, Spot on concrete overhead
				BKGD	BKGD	BKGD	BKGD	$\alpha = 6$ $\beta\gamma = 42$	Location 157, Spot on concrete overhead
				BKGD	BKGD	BKGD	BKGD	$\alpha = 4$ $\beta\gamma$=BKGD	Location 158, Spot on concrete overhead
				BKGD	NA[d]	NA	BKGD	BKGD	Rest of survey was BKGD
1A	60	20	NS[b]	BKGD	NA	NA	BKGD	BKGD	
1B	10	60	NS	BKGD	NA	NA	BKGD	BKGD	
1C	40	50	NS	BKGD	NA	NA	BKGD	BKGD	
1D	10	20	NS	BKGD	NA	NA	BKGD	BKGD	
1E	40	40	0.0089	2.5×10^{4}	BKGD	0.1	BKGD	$\alpha = 11$ $\beta\gamma$=BKGD	Air Sample 2 Location 174, Spot on concrete floor
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD
1F	30	40	NS	BKGD	NA	NA	BKGD	BKGD	Washroom
2	100	95	0.0032	1.7×10^{3}	BKGD	BKGD	BKGD	BKGD	Air Sample 3 Location 232, Spot on north wall
				BKGD	NA	NA	BKGD	BKGD	Rest of Survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey: Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2): Beta	Alpha	End Window (mR/h): Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
3 (Arena)	100	95	0.0029	BKGD[c]	NA[d]	NA	BKGD	BKGD	Air Sample 4 Locations 284-315, Arena Floor
								BKGD	Locations 316-342, Balloon smears
				BKGD	NA	NA	BKGD	BKGD	Locations 343-362, Overhead girders
				BKGD	NA	NA	BKGD	BKGD	Locations 363-370, Stairways
				BKGD	NA	NA	BKGD	BKGD	Locations 371-452, Bleachers and walls
3A	30	20	0.0193	BKGD	NA	NA	BKGD	BKGD	Air Sample 5 Store room
3B	25	10	0.0089	BKGD	NA	NA	BKGD	BKGD	Air Sample 6 Store room
3C	15	20	0.0087	BKGD	NA	NA	BKGD	BKGD	Air Sample 7 Store room
3D	10	10	0.0095	4.1×10^5	1.6×10^4	10	BKGD	NST[f]	Air Sample 8 Location 453, Radium dial on radio[h], equated to radium

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey: Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²): Beta	Alpha	End Window (mR/h): Contact	1 meter	Smear Results (dis/min-100 cm²)	Comments
3D (cont'd)				BKGD[c]	NA[d]	NA	BKGD	BKGD BKGD	Rest of survey was
3E	20	50	0.0113	BKGD	BKGD	NA	BKGD	BKGD	Air Sample 9 Store room
3F	40	30	0.0041	BKGD	BKGD	NA	BKGD	BKGD	Air Sample 10 Store room
Elevator	100	90	NS[b]	BKGD	BKGD	NA	BKGD	BKGD	Elevator to balcony
5	100	95	0.0031	1.2×10^4	BKGD	0.07	BKGD	α =BKGD[e] $\beta\gamma$=14	Location 497, Spot on concrete floor
				2.7×10^3	BKGD	BKGD	BKGD	BKGD	Location 498, Spot on concrete floor
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD
5A	60	70	NS	BKGD	NA	NA	BKGD	BKGD	
5B	20	25	0.0049	2.3×10^4	BKGD	0.1	BKGD	BKGD	Air Sample 12 Location 503, Spot on concrete floor
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm²)	Comments
5C	60	70	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
5D	60	70	NS	BKGD	NA	NA	BKGD	NST[f]	
5E	60	70	NS	BKGD	NA	NA	BKGD	BKGD	
6	60	50	NS	BKGD	NA	NA	BKGD	BKGD	Boiler room
Northwest Lobby	100	100	0.0056	BKGD	NA	NA	BKGD	BKGD	Air Sample 30
Ticket Office Northwest Lobby	60	30	NS	BKGD	NA	NA	BKGD	BKGD	
Northeast Lobby	100	100	0.0091	BKGD	NA	NA	BKGD	BKGD	Air Sample 31
Ticket Office Northeast Lobby	40	40	NS	BKGD	NA	NA	BKGD	NST	
101	40	35	NS	BKGD	NA	NA	BKGD	BKGD	
101A	80	70	NS	9.0×10^4	BKGD	1.0	BKGD	NST	Radio knobs[h], equated to radium

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm²)	Comments
101A (cont'd)				BKGD[c]	NA[d]	NA	BKGD	BKGD	Rest of survey was BKGD
103-104	70	75	NS[b]	BKGD	NA	NA	BKGD	BKGD	
105	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
106	65	80	NS	BKGD	NA	NA	BKGD	BKGD	
East-west corr.	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
107	90	80	NS	BKGD	NA	NA	BKGD	BKGD	
108/108A	70	80	NS	BKGD	NA	NA	BKGD	BKGD	
109	80	80	NS	BKGD	NA	NA	BKGD	BKGD	
110	95	5	NS	BKGD	NA	NA	BKGD	BKGD	95% Wall by offset
111	90	90	NS	BKGD	NA	NA	BKGD	BKGD	
112/113	80	80	0.0080	BKGD	NA	NA	BKGD	BKGD	Air Sample 13
114/115	80	60	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
116	85	80	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
117	50	70	NS	BKGD	NA	NA	BKGD	BKGD	
118	60	80	NS	BKGD	NA	NA	BKGD	BKGD	
119	90	60	NS	BKGD	NA	NA	BKGD	BKGD	
120	60	65	NS	BKGD	NA	NA	BKGD	BKGD	
121	60	50	NS	4.6×10^5	BKGD	2	BKGD	NST[f]	Location 1177, Radio speaker knobs[h], equated to radium
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD
122/ 123 Main Floor	80	80	0.0046	BKGD	NA	NA	BKGD	BKGD	Air Sample 14
125	50	30	NS	BKGD	NA	NA	BKGD	BKGD	
136	50	40	NS	BKGD	NA	NA	BKGD	BKGD	
136A	5	15	NS	BKGD	NA	NA	BKGD	BKGD	
136B	45	20	NS	BKGD	NA	NA	BKGD	BKGD	
137	60	10	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min·100 cm²)		End Window (mR/h)		Smear Results (dis/min·100 cm²)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
139	30	30	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
140	65	50	NS	BKGD	NA	NA	BKGD	BKGD	
141	75	80	NS	8.9×10^5	9.3×10^3	8	BKGD	NST[f]	Location 1178, Radio control knobs[h], equated to radium
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD
142	45	10	0.0076	BKGD	NA	NA	BKGD	BKGD	Air Sample 15
143	70	80	NS	BKGD	NA	NA	BKGD	BKGD	
144	80	60	NS	2.3×10^6	BKGD	5	BKGD	NST	Location 1179, Lensatic compass dial[h], equated to radium
				3.4×10^5	BKGD	0.1	BKGD	NST	Location 1180, Gas mantle[h]
				BKGD	NA	NA	NA	BKGD	Rest of survey was BKGD
145	90	85	NS	BKGD	NA	NA	NA	BKGD	Snack Shop
146	75	85	NS	BKGD	NA	NA	NA	BKGD	
146A	2	0	NS	BKGD	NA	NA	NA	BKGD	Old barber shop used as storage area

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min·100 cm^2)		End Window (mR/h)		Smear Results (dis/min·100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
147 and stairway	60	20	NS[b]	7.4×10^5	6.3×10^4	16	BKGD[c]	NST[f]	Radio knobs[h], equated to radium
				BKGD	NA[d]	NA	NA	BKGD	Rest of survey was BKGD
147A&B	80	20	NS	BKGD	NA	NA	NA	BKGD	
148	90	85	0.0091	BKGD	NA	NA	NA	BKGD	Air Sample 16
149	60	70	NS	BKGD	NA	NA	NA	BKGD	
150	100	70	NS	2.3×10^5	BKGD	6	BKGD	NST	Location 1181, Compass dial[h], equated to radium
				NRR[g]	NRR	10	BKGD	NST	Location 1182, Compass dial[h]
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD
151	70	55	NS	BKGD	NA	NA	NA	BKGD	
152	80	55	NS	BKGD	NA	NA	NA	BKGD	
176	50	25	NS	BKGD	NA	NA	NA	BKGD	
178	60	10	NS	BKGD	NA	NA	BKGD	BKGD	
180	80	80	NS	BKGD	NA	NA	NA	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
East Stair 2nd Floor	100	100	NS[b]	BKGD[c]	NA[d]	NA	NA	BKGD	
201A	80	60	NS	BKGD	NA	NA	NA	BKGD	
202	80	60	0.0074	BKGD	NA	NA	NA	BKGD	Air Sample 17
202A	80	60	NS	BKGD	NA	NA	NA	BKGD	
202B	80	75	NS	BKGD	NA	NA	NA	BKGD	
202/203	100	100	NS	BKGD	NA	NA	NA	BKGD	
203	60	70	NS	BKGD	NA	NA	BKGD	BKGD	
204	30	40	NS	BKGD	NA	NA	BKGD	BKGD	
205	60	40	NS	BKGD	NA	NA	BKGD	BKGD	
206	55	50	NS	BKGD	NA	NA	BKGD	BKGD	
207	60	60	NS	BKGD	NA	NA	BKGD	BKGD	
208	75	90	NS	BKGD	NA	NA	BKGD	BKGD	
210	25	50	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
Corridor between 210/211	100	100	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
211	55	45	NS	BKGD	NA	NA	BKGD	BKGD	
212/ 212A	35	40	NS	BKGD	NA	NA	BKGD	BKGD	
213	100	60	NS	BKGD	NA	NA	BKGD	BKGD	
214	60	65	NS	BKGD	NA	NA	BKGD	BKGD	
215	60	60	NS	BKGD	NA	NA	BKGD	BKGD	
216	60	60	NS	BKGD	NA	NA	BKGD	BKGD	
217	80	80	NS	BKGD	NA	NA	BKGD	BKGD	
218	80	80	NS	BKGD	NA	NA	BKGD	BKGD	
220	80	40	NS	BKGD	NA	NA	BKGD	BKGD	
Foyer 2nd Floor West	100	100	0.0104	BKGD	NA	NA	BKGD	BKGD	Air Sample 32
Stairs 1st to 2nd Floor west end	100	100	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
221/ 221A	100	80	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
223	60	60	NS	BKGD	NA	NA	BKGD	BKGD	
224	80	80	NS	BKGD	NA	NA	BKGD	BKGD	
225	80	80	NS	BKGD	NA	NA	BKGD	BKGD	
225A	80	75	NS	BKGD	NA	NA	BKGD	BKGD	
225B	40	90	NS	BKGD	NA	NA	BKGD	BKGD	
225C	25	30	NS	BKGD	NA	NA	BKGD	BKGD	
230	60	40	NS	BKGD	NA	NA	BKGD	BKGD	
231	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
231A	70	50	NS	BKGD	NA	NA	BKGD	BKGD	
232/ 233/ 234	100	40	NS	BKGD	NA	NA	BKGD	BKGD	
2nd floor north corridor	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
North Balcony	100	100	NS	BKGD	NA	NA	BKGD	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
240	80	60	NS[b]	BKGD[c]	NA[d]	NA	BKGD	BKGD	
242	55	20	NS	BKGD	NA	NA	BKGD	BKGD	
244	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
245	40	20	NS	BKGD	NA	NA	BKGD	BKGD	
246	100	100	0.0003	BKGD	NA	NA	BKGD	BKGD	Air Sample 18 Firing Range
246A	25	15	NS	BKGD	NA	NA	BKGD	BKGD	
246B	40	50	NS	BKGD	NA	NA	BKGD	BKGD	
2nd Floor corridor, south side	100	100	0.0027 0.0006						Air Sample 21 Air Sample 24
				1.5×10^4	BKGD	BKGD	BKGD	BKGD	Location 1080, Spot on concrete floor
				3.2×10^4	5.8×10^2	BKGD	BKGD	BKGD	Location 1081, Spot on concrete floor
				2.7×10^3	BKGD	BKGD	BKGD	BKGD	Location 1082, Spot on concrete floor

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²)		End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
2nd Floor corridor, south side (cont'd.)				BKGD[c]	NA[d]	NA	BKGD	BKGD	Rest of survey was BKGD
258	30	40	NS[b]	BKGD	NA	NA	NA	BKGD	
260	50	75	0.0024						Air Sample 19
Mess Hall				1.7×10^5	BKGD	0.3	BKGD	BKGD	Location 819, Spot on concrete floor
				6.7×10^4	BKGD	0.2	BKGD	BKGD	Location 820, Spot on concrete floor
				3.1×10^5	BKGD	0.5	BKGD	BKGD	Location 821, Spot on concrete floor
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD
261	50	75	NS	BKGD	NA	NA	BKGD	BKGD	
262	50	75	NS	BKGD	NA	NA	BKGD	NST[f]	
263	50	75	NS	BKGD	NA	NA	BKGD	NST	
266	70	95	NS	BKGD	BKGD	NA	NA	BKGD	
267	80	95	NS	BKGD	BKGD	NA	NA	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²)		End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
269	40	60	NS[b]	BKGD[c]	BKGD	NA[d]	NA	BKGD	
270	35	60	NS	BKGD	BKGD	NA	NA	BKGD	
271	40	25	NS	BKGD	NA	NA	BKGD	BKGD	
272	65	75	NS	BKGD	NA	NA	BKGD	BKGD	
273	90	85	NS	BKGD	NA	NA	BKGD	NST[f]	
274	80	75	NS	BKGD	NA	NA	BKGD	BKGD	
275	50	50	NS	BKGD	NA	NA	BKGD	BKGD	
277/ 278	35	50	NS	BKGD	NA	NA	BKGD	BKGD	
279	30	100	NS	BKGD	NA	NA	BKGD	BKGD	
280	80	80	0.0004						Air Sample 20
				1.0×10^5	BKGD	0.1	BKGD	BKGD	Location 842, Spot on brick wall
				BKGD	NA	NA	BKGD	BKGD	
281	75	60	NS	BKGD	NA	NA	BKGD	BKGD	
282	50	70	NS	BKGD	NA	NA	BKGD	BKGD	
283	50	70	0.0008						Air Sample 22
				2.2×10^3	BKGD	BKGD	BKGD	BKGD	Location 847, Spot on concrete floor

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min-100 cm^2)	Comments
283 (cont'd)				2.2×10^3	BKGD[c]	BKGD	BKGD	BKGD	Location 848, Spot on concrete floor
				BKGD	NA[d]	NA	BKGD	BKGD	Rest of survey was BKGD
284	90	10	0.0011						Air Sample 23
				1.5×10^4	BKGD	BKGD	BKGD	BKGD	Location 851, Spot on concrete floor
				BKGD	NA	NA	BKGD	BKGD	Rest of survey was BKGD
285	50	40	NS[b]	BKGD	NA	NA	NA	BKGD	
286	60	45	NS	BKGD	NA	NA	NA	BKGD	
287/288	80	80	NS	BKGD	NA	NA	NA	BKGD	
289	20	10	NS	BKGD	NA	NA	NA	BKGD	
290	75	80	NS	BKGD	NA	NA	NA	BKGD	
291	60	90	NS	BKGD	NA	NA	NA	BKGD	
292	100	100	NS	BKGD	NA	NA	NA	BKGD	
293	80	50	NS	BKGD	NA	NA	NA	BKGD	
294	70	70	NS	BKGD	NA	NA	NA	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
295	95	95	NS[b]	BKGD[c]	NA[d]	NA	NA	BKGD	
296	40	50	NS	BKGD	NA	NA	NA	BKGD	
297	30	10	0.0011	BKGD	NA	NA	NA	BKGD	Air Sample 25
298	40	45	NS	BKGD	NA	NA	NA	BKGD	
299/ 299A	80	60	NS	BKGD	NA	NA	NA	BKGD	
301 South	45	20	NS	BKGD	NA	NA	NA	BKGD	
302 South	45	40	NS	BKGD	NA	NA	NA	BKGD	
302A South	90	85	NS	BKGD	NA	NA	NA	BKGD	
303 South	50	40	NS	BKGD	NA	NA	NA	BKGD	
304 South	60	70	NS	BKGD	NA	NA	NA	BKGD	
305 South	40	35	NS	BKGD	NA	NA	NA	BKGD	
306/ 307 South	50	50	NS	BKGD	NA	NA	NA	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm²)		End Window (mR/h)		Smear Results (dis/min-100 cm²)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
308 South	50	80	NS[b]	BKGD[c]	NA[d]	NA	NA	BKGD	
310 South	70	80	0.0024	BKGD	NA	NA	NA	BKGD	Air Sample 28
311 South	35	40	NS	BKGD	NA	NA	NA	BKGD	
3rd Floor south corr.	100	90	0.0107	BKGD	NA	NA	NA	BKGD	Air Sample 27
Stairs to Gym 2nd Floor-West	80	80	NS	BKGD	NA	NA	NA	BKGD	
301 North	100	100	0.0110						Air Sample 26
				BKGD	NA	NA	NA	BKGD	Gym
302 North	70	95	NS	BKGD	NA	NA	NA	BKGD	
303 North	50	95	NS	BKGD	NA	NA	NA	BKGD	
304 North	50	85	NS	BKGD	NA	NA	NA	BKGD	

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min·100 cm^2)		End Window (mR/h)		Smear Results (dis/min·100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
305 North	60	70	NS[b]	BKGD[c]	NA[d]	NA	NA	BKGD	
306 North	80	80	NS	BKGD	NA	NA	NA	BKGD	
307 North	80	80	NS	BKGD	NA	NA	NA	BKGD	
308 North	80	75	NS	BKGD	NA	NA	NA	BKGD	Area under gym bleachers
309 North	80	80	NS	BKGD	NA	NA	NA	BKGD	Northwest tower
316 North	60	80	NS	BKGD	NA	NA	NA	BKGD	Northwest tower
317 North	35	60	NS	BKGD	NA	NA	NA	BKGD	
401 South	90	90	0.0126	BKGD	NA	NA	BKGD	BKGD	Air Sample 29
Service Floor Boiler Area	80	90	0.0056	BKGD	NA	NA	BKGD	BKGD	Air Sample 33 Boiler area

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey Floor	Wall	Air Sample (WL)	Direct Readings[a] (dis/min·100 cm^2) Beta	Alpha	End Window (mR/h) Contact	1 meter	Smear Results (dis/min·100 cm^2)	Comments
Service Floor Large Area	90	90	0.0066	BKGD[c]	NA[d]	NA	BKGD	BKGD	Air Sample 34
South-west Utility Pit	80	60	NS[b]	BKGD	NA	NA	BKGD	BKGD	
South Roof	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
South Garage (Room 2) Roof	100	100	NS	BKGD	NA	NA	BKGD	BKGD	
Drainage System for Room 1 & 5 Floors									
Catch Basin 1	0	0	NS	NRR[g]	NA	BKGD	BKGD	NST[f]	Sealed shut, in-acessible for survey
Catch Basin 2	0	0	NS	NRR	NA	BKGD	BKGD	NST	Sealed shut, in-accessible for survey

TABLE 1

DATA SHEET OF ROOM SURVEYS

Room or Area No.	Percent of Area Accessible for Survey		Air Sample (WL)	Direct Readings[a] (dis/min-100 cm^2)		End Window (mR/h)		Smear Results (dis/min-100 cm^2)	Comments
	Floor	Wall		Beta	Alpha	Contact	1 meter		
Catch Basin 3	100	100	NS[b]	5.1×10^3	NRR[g]	NRR	NRR	NST[f]	Location 1201, Area on brick catch basin
Catch Basin 4	100	100	NS	5.1×10^3	NRR	NRR	NRR	NST	Location 1199, Area on brick catch basin
Catch Basin 5	0	0	NS	NRR	NA[d]	NA	NA	NST	Sealed shut, in-accessible for survey
Catch Basin 6	100	100	NS	BKGD[c]	NA	NA	NA	NST	

FOOTNOTES FOR TABLE 1

[a]The Beta Mode Direct Readings and Alpha Mode Direct Readings are taken with PAC-4G-3 instruments (see Appendix 1). The beta mode detects both electromagnetic and particulate radiation. If an area indicated an instrument reading higher than background, a beta-mode reading was obtained. The instrument was then switched to the alpha mode, and a reading of the alpha contamination was obtained. In the alpha mode the instrument only responds to particles with high-specific ionization, such as alpha particles. The beta-mode readings were compensated for any alpha contribution by subtracting the alpha-mode reading from the beta-mode reading.

[b]NS = Not Selected. Locations of air samples were chosen on a selected basis throughout the area surveyed. "NS" indicates that the room or area was not selected for an air sample.

[c]BKGD = Background. The following are the instrument background readings:

	Beta Mode	Alpha Mode
Floor Monitor	1500-2000 cts/min-325 cm^2	0-50 cts/min-325 cm^2
PAC-4G-3	150-200 cts/min-51 cm^2	0-50 cts/min-51 cm^2
PC-5 Counter	40.0±1.4 cts/min*	0.2±0.1 cts/min*
10-Wire	443.0±4.7 cts/min*	5.2±0.5 cts/min*

GM End Window Detector read 0.03 to 0.05 mR/h at 1 m above floor.

[d]NA = Nonapplicable. No contamination was detected above background in the beta mode; therefore, no alpha mode or contact GM End Window survey was necessary.

[e]α = Alpha
$\beta\gamma$ = Beta-Gamma
(The beta-gamma readings are compensated for any alpha contamination by subtracting the alpha reading from the beta-gamma reading.)

[f]NST = No Smear Taken.

[g]NRR = No Reading Recorded.

[h]Presumably not a result of MED/AEC occupancy.

*One standard deviation due to counting statistics.

TABLE 2

RADON DETERMINATIONS

Sample Number	Location	Figure	dis/min-m^3	pCi/ℓ	WL[a]
1	Room 1	2	123	0.06	0.0006
2	Room 1E	2	1972	0.89	0.0089
3	Room 2	3	717	0.32	0.0032
4	Room 3 (Arena)	4	648	0.20	0.0029
5	Room 3A	5	4285	1.93	0.0193
6	Room 3B	5	1973	0.89	0.0089
7	Room 3C	5	1944	0.87	0.0087
8	Room 3D	5	2112	0.95	0.0095
9	Room 3E	5	2505	1.13	0.0113
10	Room 3F	5	902	0.41	0.0041
11	Room 5	6	689	0.31	0.0031
12	Room 5B	6	1091	0.49	0.0049
13	Room 112	9	1788	0.80	0.0080
14	Room 123	10	1029	0.46	0.0046
15	Room 142	12	1679	0.76	0.0076
16	Room 148	7	2031	0.91	0.0091
17	Room 202	13	1643	0.74	0.0074
18	Room 246	17	57	0.03	0.0003
19	Room 260	16	536	0.24	0.0024
20	Room 280	19	97	0.04	0.0004
21	Corridor South at Room 282	19	605	0.27	0.0027
22	Room 283	19	170	0.08	0.0008
23	Room 284	19	245	0.11	0.0011
24	2nd Floor Corridor at Room 294	20	127	0.06	0.0006
25	Room 297	20	245	0.11	0.0011
26	Room 301 North	22	2450	1.10	0.0110

TABLE 2
(cont'd)

Sample Number	Location	Figure	dis/min-m^3	pCi/ℓ	WL[a]
27	South Corridor by Room 305	21	2387	1.07	0.0107
28	Room 310 South	21	538	0.24	0.0024
29	Room 401 South	23	2810	1.26	0.0126
30	Northwest Lobby	7	1238	0.56	0.0056
31	Northeast Lobby	8	2029	0.91	0.0091
32	2nd Floor Foyer West side	15	2302	1.04	0.0104
33	Service Floor Boiler Area	24	1238	0.56	0.0056
34	Service Floor Large Area	24	1462	0.66	0.0066

Example Calculation: Air Sample 1, Room 1

$$\frac{123 \text{ dis/min}}{m^3} \times \frac{1 \text{ pCi}}{2.22 \text{ dis/min}} \times \frac{m^3}{10^3 \ \ell} \times \frac{\text{WL}}{100 \text{ pCi}/\ell} = 0.0006 \text{ WL}$$

[a]A Working Level (WL) is defined as any combination of short-lived radon-daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. The numerical value of the WL is derived from the alpha energy released by the total decay through RaC' of the short-lived radon-daughter products, RaA, RaB, and RaC at radioactive equilibrium with 100 pCi of ^{222}Rn per liter of air.

TABLE 3

SOIL SAMPLE WEIGHTS
(grams)

Sample Number	Wet Weight	Dry Weight	Sieved Weight	Rocks and Dross
3-S1-A	648.5	503.6	406.2	92.4
3-S1-B	727.5	567.5	554.0	10.7
3-S1-C	721.8	576.2	550.5	25.0
3-S1-D	2623.1	2131.2	2009.6	115.5
3-S2-A	568.5	432.3	362.8	68.6
3-S2-B	623.7	491.1	458.4	22.9
3-S2-C	767.5	612.3	590.2	15.3
3-S2-D	2446.6	2078.0	2018.3	56.5
3-S3-A	516.4	400.1	347.5	50.0
3-S3-B	532.5	390.0	323.5	55.6
3-S3-C	578.0	438.6	303.6	130.0
3-S3-D	2073.7	1745.3	1660.1	75.3
3-S4-A	689.1	546.8	532.1	2.6
3-S4-B	712.2	588.1	554.1	30.0
3-S4-C	838.4	702.3	650.6	42.8
3-S4-D	2362.2	2085.7	1890.3	192.7
3-S5-A	631.8	434.0	365.5	65.6
3-S5-B	712.3	548.8	519.1	25.4
3-S5-C	980.8	759.5	745.2	9.2
3-S5-D	1723.0	1341.3	1223.6	94.7
3-S6-A	566.9	398.8	295.9	99.3
3-S6-B	794.3	635.1	603.9	29.0
3-S6-C	907.1	772.7	719.6	49.5
3-S6-D	2556.5	2528.8	1849.5	372.7
3-S7-A	443.1	317.1	264.7	47.8
3-S7-B	790.8	588.0	550.0	36.2
3-S7-C	1068.3	913.5	878.5	33.0
3-S7-D	1946.5	1685.9	1554.7	126.0
3-S8-A	809.0	641.1	618.3	17.0
3-S8-B	691.3	474.0	444.6	27.1
3-S8-C	956.5	832.4	540.0	286.3
3-S8-D	2346.0	1927.6	1677.0	238.4
3-S9-A	776.0	661.0	642.7	14.0
3-S9-B	896.9	675.1	641.0	14.2
3-S9-C	769.0	670.7	623.7	40.4
3-S9-D	1477.2	1159.0	1095.5	56.1
3-S10	24.0	16.0	10.0	6.0

TABLE 4

GAMMA-RAY SPECTRAL AND URANIUM-FLUOROMETRIC ANALYSES OF SOIL SAMPLES

Sample Number	Ge(Li) Spectra pCi/g received wt ± $\sigma^{a,b}$ ^{137}CS	^{232}Th Decay Chain	^{226}Ra Decay Chain	Uranium μg/g ± $\sigma^{a,b}$	Uranium pCi/g ± $\sigma^{a,c}$
3-S1-A	0.62 ± 0.05	0.28 ± 0.04	0.43 ± 0.03	5.1 ± 0.3	3.6 ± 0.2
3-S1-B				3.4 ± 0.2	2.4 ± 0.1
3-S1-C				4.8 ± 0.3	3.4 ± 0.2
3-S1-D				1.5 ± 0.2	1.0 ± 0.1
3-S2-A	0.71 ± 0.06	0.15 ± 0.06	0.57 ± 0.06	0.4 ± 0.3	0.3 ± 0.2
3-S2-B				0.5 ± 0.2	0.3 ± 0.1
3-S2-C				0.7 ± 0.3	0.5 ± 0.2
3-S2-D				<0.2	<0.1
3-S3-A	3.57 ± 0.18	0.50 ± 0.13	0.64 ± 0.10	<0.3	<0.2
3-S3-B				0.7 ± 0.4	0.5 ± 0.3
3-S3-C				1.6 ± 0.4	1.1 ± 0.3
3-S3-D				1.5 ± 0.4	1.0 ± 0.3
3-S4-A	1.26 ± 0.06	0.16 ± 0.05	0.36 ± 0.05	0.6 ± 0.3	0.4 ± 0.2
3-S4-B				0.7 ± 0.3	0.5 ± 0.2
3-S4-C				0.4 ± 0.2	0.3 ± 0.1
3-S4-D				0.4 ± 0.3	0.3 ± 0.2
3-S5-A	1.54 ± 0.08	0.35 ± 0.13	0.56 ± 0.11	1.6 ± 0.3	1.1 ± 0.2
3-S5-B				1.4 ± 0.3	1.0 ± 0.2
3-S5-C				1.1 ± 0.3	0.8 ± 0.2
3-S5-D				1.3 ± 0.3	0.9 ± 0.2
3-S6-A	2.13 ± 0.11	0.48 ± 0.11	0.68 ± 0.09	1.4 ± 0.3	1.0 ± 0.2
3-S6-B				1.5 ± 0.3	1.0 ± 0.2
3-S6-C				0.5 ± 0.2	0.3 ± 0.1
3-S6-D				0.6 ± 0.3	0.4 ± 0.2
3-S7-A	2.51 ± 0.13	0.39 ± 0.09	0.47 ± 0.07	1.6 ± 0.3	1.1 ± 0.2
3-S7-B				0.6 ± 0.3	0.4 ± 0.2
3-S7-C				0.4 ± 0.3	0.3 ± 0.2
3-S7-D				<0.3	<0.2
3-S8-A	0.91 ± 0.05	0.26 ± 0.08	0.30 ± 0.07	<0.3	<0.2
3-S8-B				0.4 ± 0.3	0.3 ± 0.2
3-S8-C				1.8 ± 0.3	1.3 ± 0.2
3-S8-D				0.9 ± 0.3	0.6 ± 0.2

TABLE 4
(cont'd)

Sample Number	Ge(Li) Spectra pCi/g received wt ± $\sigma^{a,b}$ ^{137}CS	^{232}Th Decay Chain	^{226}Ra Decay Chain	Uranium $\mu g/g \pm \sigma^{a,b}$	$pCi/g \pm \sigma^{a,c}$
3-S9-A	0.90 ± 0.05	0.28 ± 0.06	0.42 ± 0.05	0.6 ± 0.4	0.4 ± 0.3
3-S9-B				0.7 ± 0.3	0.5 ± 0.2
3-S9-C				0.7 ± 0.3	0.5 ± 0.2
3-S9-D				1.7 ± 0.3	1.2 ± 0.2
3-S10[d]	3.3 ± 1.1	3 ± 1	1 ± 1	$1.5 \times 10^4 \pm 10\%$	$1.1 \times 10^4 \pm 10\%$

[a]One standard deviation due to counting statistics.

[b]All data results from LFE, except for 3-S10 from ANL. All data decay corrected to 3/30/78.

[c]ANL conversion from Appendix 5.

[d]Sample 3-S10 consisted of sludge/dirt collected from Catch Basin 3 of the floor drainage system for Rooms 1 and 5. The gamma-ray spectral analysis indicated that the sample also contained 7.4 ± 1.2 pCi/g ^{152}Eu (decay corrected to 3/30/78). Mass spectral analysis indicated that the uranium present in the sample was normal uranium.

TABLE 5

BACKGROUND SOIL SAMPLE DATA[a]
Radionuclides in Soil, 1978
(Concentration in pCi/g)

Date Collected	Locations	Cesium-137	Thorium-232	Uranium (natural)
June 23	Argonne Area[b]	0.8 ± 0.2	0.26 ± 0.02	1.0 ± 0.1
June 23	Argonne Area	0.3 ± 0.1	0.60 ± 0.04	2.2 ± 0.2
June 23	Argonne Area	1.3 ± 0.3	0.40 ± 0.03	1.3 ± 0.1
June 23	Argonne Area	1.2 ± 0.3	0.38 ± 0.03	1.5 ± 0.1
June 23	Argonne Area	1.2 ± 0.3	0.38 ± 0.3	1.7 ± 0.1
October 17	Argonne Area	3.0 ± 0.7	0.18 ± 0.02	1.2 ± 0.1
October 17	Argonne Area	1.3 ± 0.4	0.36 ± 0.04	1.0 ± 0.1
October 17	Argonne Area	1.1 ± 0.3	0.40 ± 0.04	1.2 ± 0.3
October 17	Argonne Area	1.5 ± 0.4	0.48 ± 0.04	1.3 ± 0.2
October 17	Argonne Area	1.0 ± 0.3	0.40 ± 0.02	1.5 ± 0.2
	Average	1.3 ± 0.4	0.38 ± 0.07	1.4 ± 0.2
June 16	Naperville, IL	1.2 ± 0.3	0.53 ± 0.03	1.6 ± 0.2
June 20	Channahon, IL	1.1 ± 0.3	0.36 ± 0.02	1.5 ± 0.1
June 20	Morris, IL	1.2 ± 0.3	0.27 ± 0.03	1.2 ± 0.1
June 20	Starved Rock State Park, IL	0.9 ± 0.3	0.19 ± 0.02	0.6 ± 0.1
June 21	Willow Springs, IL	0.9 ± 0.3	0.31 ± 0.03	1.4 ± 0.1
October 19	McKinley Woods State Park, IL	1.3 ± 0.4	0.39 ± 0.05	1.4 ± 0.3
October 19	Dresden Lock and Dam, IL	1.6 ± 0.5	- - - -	1.3 ± 0.1
October 20	Romeoville, IL	2.9 ± 0.7	0.42 ± 0.04	2.2 ± 0.3
October 20	Lemont, IL	0.8 ± 0.3	0.37 ± 0.04	1.1 ± 0.1
October 20	McGinnis Slough, IL	1.3 ± 0.4	0.37 ± 0.04	1.6 ± 0.1
October 20	Saganashkee Slough, IL	1.1 ± 0.3	0.37 ± 0.04	1.8 ± 0.1
	Average	1.3 ± 0.3	0.36 ± 0.06	1.4 ± 0.2

[a]These results are transcribed from "Environmental Monitoring at Argonne National Laboratory: Annual Report for 1978" (ANL-79-24) by N. W. Golchert, T. L. Duffy, and J. Sedlet.

[b]All samples marked "Argonne Area" were collected at Argonne National Laboratory near Lemont, IL, southwest of Chicago.

TABLE 6

LOCATIONS WHERE MED/AEC RESIDUAL CONTAMINATION EXCEEDED ACCEPTABLE LIMITS[a,b]

Room Number	Location Number	Estimated Area of Contamination (cm^2)	Maximum PAC Reading (dis/min-100 cm^2)		Contact GM Reading (mR/h)	Smear Results (dis/min-100 cm)	
			Beta-Gamma	Alpha		Beta-Gamma	Alpha
1	97	300	$2.1x10^4$	BKGD[c]	0.3	BKGD	BKGD
	98	300	$2.1x10^4$	BKGD	2.0	BKGD	BKGD
	99	300	$1.0x10^4$	BKGD	0.1	BKGD	BKGD
	100	300	$1.2x10^4$	$3.7x10^2$	0.1	18	6
	101	300	$3.4x10^4$	BKGD	0.1	BKGD	BKGD
	102	300	$1.6x10^4$	BKGD	BKGD	BKGD	BKGD
	103	300	$2.0x10^4$	BKGD	BKGD	BKGD	BKGD
	104	300	$3.4x10^5$	BKGD	3.0	$1.3x10^3$	470
	105	300	$2.3x10^4$	BKGD	0.12	BKGD	BKGD
	107	300	$2.0x10^4$	BKGD	0.2	BKGD	BKGD
	121	2000[d]	$6.7x10^4$	$5.8x10^4$	0.1	$2.5x10^3$	$1.7x10^3$
	126	500[d]	$1.5x10^4$	$2.9x10^4$	BKGD	760	500
	127	500[d]	$3.1x10^4$	$6.9x10^3$	BKGD	140	175
	128	500[d]	$6.3x10^4$	$6.9x10^3$	BKGD	140	170
	129	500[d]	$6.3x10^4$	$6.9x10^3$	--	59	33
	131	500[d]	$1.5x10^5$	$2.9x10^4$	0.2	250	140
	132	500[d]	$5.4x10^4$	BKGD	--	920	510
	133	500[d]	$1.7x10^5$	$5.8x10^4$	0.5	$1.2x10^3$	710
	134	500[d]	$2.6x10^4$	$1.2x10^4$	BKGD	95	90
	135	500[d]	$1.6x10^4$	BKGD	BKGD	170	210
	136	500[d]	$2.3x10^4$	$1.7x10^4$	BKGD	140	92
	137	500[d]	$5.7x10^4$	$1.7x10^4$	0.1	170	84
	138	500[d]	$1.5x10^5$	$3.5x10^4$	0.1	$1.0x10^3$	830
	139	500[d]	$1.4x10^5$	$5.8x10^4$	0.5	$1.2x10^3$	800
	146	500[d]	$9.3x10^3$	BKGD	BKGD	41	23
	147	500[d]	$1.1x10^4$	$2.3x10^3$	BKGD	28	25
	151	500[d]	$9.3x10^3$	BKGD	BKGD	87	38
	152	500[d]	$1.3x10^4$	BKGD	BKGD	55	49

TABLE 6 (continued)

Room Number	Location Number	Estimated Area of Contamination (cm^2)	Maximum PAC Reading ($dis/min\text{-}100\ cm^2$)		Contact GM Reading (mR/h)	Smear Results (dis/min-100 cm)	
			Beta-Gamma	Alpha		Beta-Gamma	Alpha
	155	500[d]	1.4×10^5	5.8×10^4	0.5	405	330
	156	500	1.4×10^5	5.8×10^4	0.3	1.8×10^3	1.4×10^3
1E	174	300	2.5×10^4	BKGD	0.1	BKGD	11
5	497	300	1.2×10^4	BKGD	0.07	14	BKGD
5B	503	300	2.3×10^4	BKGD	0.1	BKGD	BKGD
2nd Floor Corr.	1080	300	1.5×10^4	BKGD	BKGD	BKGD	BKGD
	1081	300	3.2×10^4	5.8×10^2	BKGD	BKGD	BKGD
260	819	10^4	1.7×10^5	BKGD	0.3	BKGD	BKGD
	820	10^4	6.7×10^4	BKGD	0.2	BKGD	BKGD
	821	10^4	3.1×10^5	BKGD	0.5	BKGD	BKGD
280	842	300	1.0×10^5	BKGD	0.1	BKGD	BKGD
284	851	300	1.5×10^4	BKGD	BKGD	BKGD	BKGD
Drainage System for Room 1 and 5 Floors	1199	10^4	5.1×10^3	--	--	--	--
	1201	10^4	5.1×10^3	--	--	--	--

[a]Locations are indicated in Table 1 and Figures 2-26.

[b]The surface contamination limits for uranium as given in the ANSI Standard N13.12 and the average and maximum radiation levels at 1 cm as given in the NRC Guidelines were used as the standards for "acceptable levels" of contamination.

[c]BKGD = Background.

[d]Estimated area of higher readings. Total area of contaminated overheads is estimated as 200 m^2.

TABLE 7

ESTIMATED VOLUME, MASS, AND ACTIVITY OF MATERIAL THAT COULD BE GENERATED BY REMEDIAL ACTION[a]

Type of Material	Estimated Volume (m^3)	Estimated Mass (kg)	Estimated Activity (μCi)
Concrete (ρ=2.35)[b]	1.0×10^1	2.4×10^4	2.9×10^1
Brick (ρ=2.2)	1.1×10^{-1}	2.3×10^2	5.9×10^{-1}
Iron (ρ=7.8)	8.7×10^{-3}	6.8×10^1	4.6×10^{-1}
Total	1.05×10^1 m^3	2.5×10^4 kg	3.0×10^1 μCi

[a]See text for assumptions upon which estimates are based.

[b]The assumed density for the purpose of calculating mass of material.

APPENDIX 1

INSTRUMENTATION

I. PORTABLE RADIATION SURVEY METERS

A. Gas-Flow Proportional Survey Meters

The Eberline PAC-4G-3 was the primary instrument used for surveying. This instrument is a gas-flow proportional alpha counter which utilizes a gas-proportional probe, 51 cm^2 (PAC-4G-3) or 325 cm^2 (FM-4G) in area, with a thin double-aluminized Mylar window (~0.85 mg/cm^2).

Since this instrument has three high-voltage positions, it can be used to distinguish between alpha and beta-gamma contamination. This instrument was initially used in the beta mode. In the beta mode, the detector responds to alpha and beta particles and x- and gamma-rays. When areas indicated a higher count rate than the average instrument background, the beta-mode reading was recorded, and the instrument was then switched to the alpha mode to determine any alpha contribution. In the alpha mode, the instrument only responds to particles with high specific ionization. This instrument is calibrated in the alpha mode with a flat-plate infinitely thin NBS traceable ^{239}Pu standard, and in the beta mode with a flat-plate infinitely thin NBS traceable ^{90}Sr-^{90}Y standard. The PAC-4G-3 instruments are calibrated to an apparent 50% detection efficiency.

B. Beta-Gamma End Window Survey Meter

When an area of contamination is found with a PAC instrument, a reading is taken with an Eberline Beta-gamma Geiger-Mueller Counter Model E-530 with a HP-190 probe. This probe has a thin mica end window and is, therefore, sensitive to alpha and beta particles and x- and gamma-rays. A thin piece of aluminum is added to the mica, thus making the window density ~7 mg/cm^2. At this density, the instrument is not sensitive to alpha particles. A maximum reading is obtained with the probe placed in contact with the area of contamination. In this position, the response (in mR/h) to gamma radiation is generally conservative relative to a determination of mrad/h at 1 cm; however, the response (in mR/h) to beta radiation is nonconservative by a factor of up to about four relative to a determination of mrad/h through 7 mg/cm^2. Another reading is obtained with the probe held 1 m from the contaminated area. This instrument is calibrated in mR/h with a ^{226}Ra standard source.

C. Low-Energy Gamma Scintillation Survey Meter

An Eberline Pulse Rate Meter Model PRM-5-3 with a PG-2 Low Energy Gamma Scintillation Detector was used to detect low-energy x and gamma radiation. The detector consists of a thin scintillation crystal, 5.1 cm in diameter by 2 mm thick NaI(Tl) with a 0.025-mm-thick aluminum window. (~7 mg/cm^2). This instrument is calibrated with NBS traceable ^{239}Pu, ^{241}Am, and ^{235}U sources.

D. High-Energy Micro "R" Scintillation Survey Meter

An Eberline Micro-R meter, Model PRM-7, was used to detect high-energy gamma radiation. This instrument contains an internally mounted 2.5-cm diameter by 2.5-cm-long NaI(Tl) scintillation crystal and can be used for counting fields of low-level radiation from 10 to 5000 μR/h. This instrument is calibrated with an NBS traceable ^{137}Cs source.

II. SMEAR-COUNTING INSTRUMENTATION

The 10-Wire instrument consists of a gas-flow proportional probe (ANL design) which uses an Eberline Mini Scaler Model MS-2. The double-aluminized Mylar probe (400 cm^2) uses P-10 (90% argon and 10% methane) as the counting gas. This system consists of two Mini Scalers and two probes. One is used for counting in the alpha mode; the other is used in the beta mode. The metal smear holder has been machined so that it can hold ten smears. The probe is placed over the smears and a count is taken.

All smears of contaminated areas are counted in a Nuclear Measurements Corporation PC-5 Gas-Flow Proportional Counter (PC counter) using a double-aluminized Mylar spun top. The Mylar spun top is placed over nonconducting media such as paper to negate the dielectric effect. This counter also uses P-10 counting gas. Smears are counted in both the alpha and beta modes of the detector. These instruments are calibrated using ^{239}Pu and ^{90}Sr-^{90}Y NBS traceable sources.

III. AIR-SAMPLING DEVICE

The air samples were collected with a commercial vacuum cleaner modified at ANL. The air was drawn at a flow rate of 40 m^3/h. The collection medium consisted of a 200 cm^2 sheet of Hollingsworth-Vose (HV-70-0.23 mm) filter paper. The collection efficiency at this flow rate for 0.3-micron particles is about 99.9%.

IV. GAMMA-SPECTRAL INSTRUMENTATION

A Nuclear Data Multichannel Analyzer Model ND-100 with a 7.6 cm diameter by 7.6 cm long NaI(Tℓ) crystal, was used to determine the gamma spectrum. This instrument was calibrated with NBS traceable sources. Samples of contaminated areas were counted with the analyzer, and the radionuclides of contamination were determined.

V. INSTRUMENTATION USED IN SURVEY

	Inventory Number	Probe Area	Window Thickness, mg/cm^2
Eberline Floor Monitor FM-4G using a PAC-4G-3	181501	325 cm^2	~0.85

APPENDIX 1
(cont'd)

	Inventory Number	Probe Area	Window Thickness mg/cm^2
Eberline Floor Monitor FM-4G using a PAC-4G-3	183413	325 cm^2	~0.85
PAC-4G-3	183414	51 cm^2	~0.85
PAC-4G-3	183415	51 cm^2	~0.85
PAC-4G-3	183416	51 cm^2	~0.85
PAC-4G-3	184339	51 cm^2	~0.85
PAC-4G-3	184340	51 cm^2	~0.85
PAC-4G-3	184341	51 cm^2	~0.85
Eberline 530 with HP-190 Beta-Gamma End Window Probe	184576	-	~7
Eberline Pulse Rate Meter Model PRM-5-3 with a Model PG-2 Low-Energy Gamma Detector	184344	5 cm x 2 mm NaI(Tℓ)	~7
Eberline Micro-R meter Model PRM-7	188537	2.5 cm x 2.5 cm NaI(Tl)	
Nuclear Measurements Corp. PC-5 2π Internal-Gas-Flow Counter	184065	-	~0.85
Argonne National Laboratory 10-Wire Flat-Plate Gas-Flow Proportional Detector Eberline Mini Scaler MS-2	184342 & 184343	400 cm^2	~0.85
Argonne National Laboratory Filter Queen Air Sampler using HV-70 filter media	-	-	-
Nuclear Data Multichannel Analyzer Model ND-100 with 7.6 cm dia x 7.6 cm NaI(Tℓ) crystal	184764	-	-

VI. AVERAGE INSTRUMENT BACKGROUND READINGS

Instrument	Alpha Mode (cts/min)	Beta Mode (cts/min)	1 m above floor
Eberline Floor Monitor FM-4G using PAC-4G-3			
181501	0-50	1500-2000	
183413	0-50	1500-2000	

APPENDIX 1
(cont'd)

Instrument	Alpha Mode (cts/min)	Beta Mode (cts/min)	1 m above floor
Eberline PAC-4G-3			
183414	0-50	150-200	
183415	0-50	150-200	
183416	0-50	150-200	
184339	0-50	150-200	
184340	0-50	150-200	
184341	0-50	150-200	
Eberline 530 With HP-190 Beta-Gamma End Window Probe			0.03-0.05 mR/h
Eberline Pulse Rate Meter Model PRM-5-3 with a Model PG-2 Low Energy Gamma Detector			500 cts/min
Eberline Micro R Meter Model PRM-7			5-7 μR/h
Nuclear Data Multichannel Analyzer Model 100	-	-	
Nuclear Measurements Corporation PC-5 2π Internal Gas-Flow Counter	0.2±0.1[b]	40.0±1.4[b]	
Argonne National Laboratory 10-Wire Flat-Plate Gas-Flow Proportional Detector with Eberline Mini Scaler MS-2	5.2±0.5	443.0±4.7	

[a]Background readings were initially taken in the mobile laboratory and rechecked throughout the various areas while surveying.

[b]One standard deviation due to counting statistics.

APPENDIX 2

CONVERSION FACTORS

I. INSTRUMENTATION

The conversion factors used to convert the instrument readings into units of disintegrations per minute per 100 cm^2 (dis/min-100 cm^2) and the derivation of those factors are given below.

A. Conversion Factors

	PAC-4G-3		Floor Monitor (FM-4G)	
	Alpha	Beta	Alpha	Beta
To 100 cm^2	1.96	1.96	0.31	0.31
cts/min to dis/min ^{239}Pu	2	-	2	-
cts/min to dis/min ^{90}Sr-^{90}Y	-	2	-	2
cts/min to dis/min for normal uranium	5.9	3.5	5.9	3.5
cts/min to dis/min ^{226}Ra plus daughters	1.6	4.7	-	-

B. Derivation of Conversion Factors

- Floor Monitor (FM-4G)

  Window Area: ~325 cm^2
  Conversion to 100 cm^2 = 0.31 times Floor Monitor readings

- PAC-4G-3

  Window Area: ~51 cm^2
  Conversion to 100 cm^2 = 1.96 times PAC reading

- 2π Internal Gas Flow Counter, PC-5

  Geometry: Solid Steel Spun Top - 0.50

  Geometry: Mylar Spun Top - 0.43
  Mylar spun top counting [double-aluminized Mylar window (~0.85 mg/cm^2)] utilizes the well of the PC-5 and is a method developed and used by the Argonne National Laboratory Health Physics Section for negating the dielectric effect in counting samples on nonconducting media.

With a 3.2 x 3.2 x 0.3 cm normal uranium plate as a source of uranium-alpha emissions, the plate was counted in the well of a 2π Internal-Gas-Flow Counter (PC Counter) with the source leveled to an apparent 2π geometry. The alpha reading was found to be 4.7×10^4 cts/min, or $4.7 \times 10^4 \div 0.50 = 9.4 \times 10^4$ dis/min with the PC Counter.

The same uranium source, when counted in the alpha mode of the PAC instrument, was found to be 1.6×10^4 cts/min at contact. The conversion factor for cts/min to dis/min for the PAC instrument is $9.4 \times 10^4 \div 1.6 \times 10^4 = 5.9$ dis/min alpha to cts/min alpha.

The same normal uranium source covered with two layers of conducting paper, each 6.65 mg/cm^2 to absorb the alpha emissions, was counted for composite beta and gamma emissions in the PC counter; however, no provision was made for backscatter. The composite beta-gamma count was found to be 5.2×10^5 cts/min or $5.2 \times 10^5 \div 0.50 = 1.04 \times 10^6$ dis/min beta-gamma.

The covered normal uranium source, when centered on the probe and counted in the beta mode with the PAC instrument, gave 3.0×10^5 cts/min. The conversion factor for cts/min to dis/min is $1.04 \times 10^6 \div 3.0 \times 10^5 = 3.5$ dis/min beta-gamma to cts/min beta gamma.

A similar method was used to determine the conversion factors for ^{226}Ra plus daughters.

II. SMEAR COUNT

The conversion factors for cts/min-100 cm^2 to dis/min-100 cm^2 for smears are given below.

A. Conversion Equation (Alpha)

$$\frac{\text{cts/min} - (\text{Bkgd})}{\text{g} \cdot \text{bf} \cdot \text{sa} \cdot \text{waf}} = \text{dis/min } \alpha$$

A geometry (g) of 0.43 is standard for all flat-plate counting using the Mylar spun top.

A backscatter factor (bf) of 1.0 is used when determining alpha activity on a filter media.

The self-absorption factor (sa) was assumed to be 1, unless otherwise determined.

If the energies of the isotope were known, the appropriate window air factor (waf) was used; if the energies of the isotopes were unknown, the (waf) of ^{239}Pu (0.713) was used.

The (waf) for normal-uranium alphas is 0.54.

The (waf) for alphas from ^{226}Ra plus daughters is 0.55.

APPENDIX 2
(cont'd)

B. Conversion Equation (Beta)

$$\frac{\text{cts/min} - [\text{Beta Bkgd (cts/min)} + \alpha\ \text{cts/min}]}{g \cdot bf \cdot sa \cdot waf} = \text{dis/min}\ \beta$$

A geometry (g) of 0.43 is standard for all flat-plate counting using the Mylar spun top.

A backscatter factor (bf) of 1.1 is used when determining beta activity on a filter media.

A self-absorption factor (sa) was assumed to be 1, unless otherwise determined.

If the energies of the isotopes were known, the appropriate window air factor (waf) was used; if the energies of the isotopes were unknown, the (waf) of ^{90}Sr-^{90}Y (0.85) was used.

The (waf) for normal-uranium betas is 0.85.

The (waf) for betas from ^{226}Ra plus daughters is 0.85.

APPENDIX 3

RADON-DETERMINATION CALCULATIONS

The air-sampling calculations for samples collected with an Argonne National Laboratory-designed air sampler with HV-70 filter media are summarized in this appendix. The appendix includes the basic assumptions and calculations used to derive the air concentrations.

I. RADON CONCENTRATIONS BASED ON RaC' RESULTS

The following postulates are assumed in deriving the radon-222 (^{222}Rn) concentrations as based on the RaC' alpha count results:

A. RaA, RaB, RaC, and RaC' are in equilibrium.

B. RaA is present only in the first count and not the 100-minute decay count.

C. One-half of the radon progeny is not adhered to airborne particulates and therefore is not collected on the filter media.

D. The geometry factor (g) is 0.43 for both the alpha and beta activity.

E. The backscatter factor (bf) of 1.0 is used for the alpha activity, which is determined from RaC'.

F. The sample absorption factor (sa) for RaC' is 0.77.

G. The window air factor (waf) for RaC' is 0.8.

H. RaB and RaC, being beta emitters, are not counted in the alpha mode.

I. The half-life of the radon progeny is approximately 36 minutes, based on the combined RaB and RaC half-lives.

J. No long-lived alpha emitters are present, as evidenced by the final count.

K. For all practical purposes, RaC' decays at the rate of the composite of RaB and RaC, which is about 36 minutes.

II. EQUATIONS USED TO DERIVE AIR CONCENTRATIONS

The activity present at the end of the sampling period is determined by the equation:

$$A_o = \frac{A}{e^{-\lambda t}}$$

Where: A_o = Activity (dis/min) present at the end of the sampling period (usually 40 min)

A = Activity (dis/min) at some time, t, after end of sampling period

t = Time interval (min) from end of sampling period to counting interval (usually ~ 100 min)

$\lambda = \frac{0.693}{t_{1/2}}$

$t_{1/2}$ = Half-life of isotope (min)

Concentration (C) is determined by the equation:

$$C = \frac{A_o\lambda}{f} \cdot \frac{1}{1-e^{-\lambda t_s}}$$

Where: C = Concentration (dis/min-m^3)

A_o = Activity on filter media at end of sampling period (dis/min)

f = Sampling rate (m^3/min = m^3/h x 1h/60 min)

t_s = Length of sampling time (min)

$\lambda = \frac{0.693}{t_{1/2}}$

$t_{1/2}$ = Half-life of isotope or controlling parent (min).

III. EXAMPLE CALCULATION

Data obtained from air sample 4, collected in Room 3, have been used to illustrate the application of the equations for determining activity and concentration.

$$A_o = \frac{876}{\exp \frac{-0.693 \cdot 100}{36}} = 6004 \text{ dis/min}$$

$$C = \frac{6004 \cdot \frac{0.693}{36}}{40/60} \cdot \frac{1}{1 - \exp \frac{-0.693 \cdot 40}{36}}$$

$$= 324 \text{ dis/min-m}^3.$$

APPENDIX 3
(cont'd)

Since we assume that half of the radon progeny is not adhered to the airborne particulates, the above concentration is multiplied by a factor of two to determine the actual concentration:

$$C_{actual} = C_{measured} \times \text{progeny correction factor}$$

$$= 324 \text{ dis/min-m}^3 \times 2 = 648 \text{ dis/min-m}^3$$

The resultant concentration is thus 648 dis/min-m^3.

APPENDIX 4

SOIL-ANALYSIS PROCEDURE FOR TOTAL URANIUM AND GAMMA-EMITTING NUCLIDES*

A 60-milliliter volume of the received soil was counted in a petri dish for 500 minutes on a Ge(Li) detector over the energy range 0-1.5 MeV. This corresponded to 60-100 g of soil, depending upon bulk soil density. Positive photopeaks above instrument background were converted to dis/min using a line efficiency curve based upon a National Bureau of Standards Multi-Gamma standard. The natural thorium-232 (^{232}Th) and radium-226 (^{226}Ra) decay chains were calculated using the 0.910 MeV actinium-228 (^{228}Ac) and 0.609 MeV bismuth-214 (^{214}Bi) photopeaks, respectively. Cesium-137 is reported for each sample as a representative gamma emitter. Potassium-40 (^{40}K) was observed on all soil samples, as expected, but was not calculated or reported.

One gram of the soil sample was ashed and dissolved in $HF\text{-}HNO_3$ for the total uranium analysis. A 100-λ aliquot of the dissolved sample was fused with 98% NaF-2% LiF and the fluorescence determined using a Jarrell-Ash fluorometer. A quenching factor was determined for each sample by using an internal spike.

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*The procedures used by LFE Environmental Analysis Laboratories to analyze the soil samples collected near the National Guard Armory.

APPENDIX 5

CALCULATION OF NORMAL-URANIUM SPECIFIC ACTIVITY

Radioactive half-lives of ^{234}U, ^{235}U, and ^{238}U, as well as the percent abundance for each isotope, were obtained as current best values from the "Table of Isotopes"--6th Edition by C.M. Lederer, J.M. Hollander, and I. Perlman, 1967. The values used are:

Isotope	Half-life (years)	% Abundance
^{234}U	2.47×10^5	0.0057
^{235}U	7.1×10^8	0.7196
^{238}U	4.51×10^9	99.2760
		100.0013

Note that the abundance totals 100.0013%. Since it cannot be determined which isotope(s) are in error, the calculations are made with the 0.0013% error unaccounted for.

Specific activity, or activity per unit mass, is determined by the equation:

$$SpA = \lambda N$$

where: SpA = Specific Activity

$\lambda = \ell n2/t_{\frac{1}{2}}$

N = Number of radioactive atoms per unit mass

$$= \frac{\text{Avogadro's Number}}{\text{gram atomic weight}}$$

Avogadro's Number = 6.025×10^{23}

$t_{\frac{1}{2}}$ = Half-life in years (a)

Therefore:

$$SpA = (\ell n2)N/t_{\frac{1}{2}}$$

$$= \frac{0.693 \times 6.025 \times 10^{23}}{t_{\frac{1}{2}}(a) \times 5.256 \times 10^5 \frac{\text{min}}{\text{a}} \times \text{gram atomic weight}} = \text{dis/min-gram.}$$

For ^{234}U, the specific activity would be:

$$SpA\ ^{234}U = \frac{0.693 \times 6.025 \times 10^{23}}{2.47 \times 10^{5} \times 5.256 \times 10^{5} \times 2.34 \times 10^{2}}$$

$= 1.374 \times 10^{10}$ dis/min-gram

$= 1.374 \times 10^{4}$ dis/min-μg $\times 5.70 \times 10^{-5}$

$= 0.783$ dis/min-μg of normal uranium.

For ^{235}U, the specific activity would be:

$$SpA\ ^{235}U = \frac{0.693 \times 6.025 \times 10^{23}}{7.1 \times 10^{8} \times 5.256 \times 10^{5} \times 2.35 \times 10^{2}}$$

$= 4.76 \times 10^{6}$ dis/min-gram

$= 4.76$ dis/min-μg $\times 7.196 \times 10^{-3}$

$= 0.034$ dis/min-μg of normal uranium.

For ^{238}U, the specific activity would be:

$$SpA\ ^{238}U = \frac{0.693 \times 6.025 \times 10^{23}}{4.51 \times 10^{9} \times 5.256 \times 10^{5} \times 2.38 \times 10^{2}}$$

$= 7.4 \times 10^{5}$ dis/min-gram

$= 0.74$ dis/min-μg $\times 9.9276 \times 10^{-1}$

$= 0.735$ dis/min-μg of normal uranium.

Therefore, the activity of 1 μg of normal uranium is

0.783 dis/min ^{234}U + 0.034 dis/min ^{235}U + 0.735 dis/min ^{238}U

= 1.552 dis/min-μg.

Conversion of μg/g to pCi/g

$$= \frac{1.552 \text{ dis/min-μg}}{2.22 \text{ dis/min-pCi}}$$

= 0.6991 pCi/μg normal uranium

Example Calculation: 3-S1-A

5.1 ± 0.3 μg/gram x 0.6991 pCi/μg = 3.6 ± 0.2 pCi/gram.

APPENDIX 6

PERTINENT RADIOLOGICAL REGULATIONS STANDARDS, AND GUIDELINES

I. Excerpts From

DRAFT AMERICAN NATIONAL STANDARD

N13.12

Control of Radioactive Surface Contamination

On Materials, Equipment, and Facilities to be

Released for Uncontrolled Use

Where potentially contaminated surfaces are not accessible for measurement (as in some pipes, drains, and ductwork), such property shall not be released pursuant to this standard, but shall be made the subject of case-by-case evaluation.

Property shall not be released for uncontrolled use unless measurements show the total and removable contamination levels to be no greater than the values in Table 1 or Table 2. (The values in Table 2 are easier to apply when the contaminants cannot be individually identified.)

Coatings used to cover the contamination shall not be considered a solution to the contamination problem. That is, the monitoring techniques shall be sufficient to determine, and such determination shall be made, that the total amount of contamination present on and under any coating does not exceed the Table 1 or Table 2 values before release.

APPENDIX 6
(cont'd)

TABLE 1

SURFACE CONTAMINATION LIMITS*

Contaminants			Limit (Activity)$^{+}$ (dis/min-100 cm^2)	
Group	Description	Nuclides (Note 1)	Removable	Total (Fixed plus Removable)
1	Nuclides for which the nonoccupational MPC_a (Note 2) is 2×10^{-13} Ci/m^3 or less or for which the nonoccupational MPC_w (Note 4) is 2×10^{-7} Ci/m^3 or less	^{227}Ac $^{241,242m,243}Am$ $^{249,250,251,252}Cf$ $^{243,244,245,246,247,248}Cm$ $^{125,129}I$ ^{237}Np ^{231}Pa ^{210}Pb $^{238,239,240,242,244}Pu$ $^{226,228}Ra$ $^{228,230}Th$	20	Nondetectable (Note 3)
2	Those nuclides not in Group 1 for which the nonoccupational MPC_a (Note 2) is 1×10^{-12} Ci/m^3 or less or for which the nonoccupational MPC_w (Note 4) is 1×10^{-6} Ci/m^3 or less	^{254}Es ^{256}Fm $^{126,131,133}I$ ^{210}Po ^{223}Ra ^{90}Sr ^{232}Th ^{232}U	200	2000 α Nondetectable β,γ (Note 5)
3	Those nuclides not in Group 1 or Group 2		1000	5000

APPENDIX 6
(cont'd)

SURFACE CONTAMINATION LIMITS*

*The levels may be averaged over one square meter provided the maximum activity in any area of 100 cm^2 is less than three times the limit value. For purposes of averaging with regard to isolated spots of activity, any square meter of surface shall be considered to be contaminated above the limit L, applicable to 100 cm^2, if (1) from measurements of a representative number n of sections it is determined that $1/n\ \Sigma_n\ S_i \geq L$, where S_i is the dis/min-100 cm^2 determined from measurement of section i; or (2) it is determined that the activity of all isolated spots or particles in any area less than 100 cm^2 exceeds 3 L.

+Disintegrations per minute per square decimeter.

NOTES:

(1) Values presented here are obtained from the Code of Federal Regulations, Title 10, Part 20, April 30, 1975. The most limiting of all given MPC values (for example, soluble versus insoluble) are to be used. In the event of the occurrence of mixtures of radionuclides, the fraction contributed by each constituent of its own limit shall be determined and the sum of the fraction shall be less than 1.

(2) Maximum permissible concentration in air applicable to continuous exposure of members of the public as published by or derived from an authoritative source such as the National Committee on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), or the Nuclear Regulatory Commission (NRC). From the Code of Federal Regulations, Title 10, Part 20, Appendix B, Table 2, Column 1.

(3) The instrument utilized for this measurement shall be calibrated to measure at least 100 pCi of any Group 1 contaminants uniformly spread over 100 cm^2.

(4) Maximum permissible concentration in water applicable to members of the public.

(5) The instrument utilized for this measurement shall be calibrated to measure at least 1 nCi of any Group 2 beta or gamma contaminants uniformly spread over an area equivalent to the sensitive area of the detector. Direct survey for unconditional release should be performed in areas where the background is $\leq$ 100 counts per minute. When the survey must be performed in a background exceeding 100 counts per minute, it may be necessary to use the indirect survey method to provide the additional sensitivity required.

ALTERNATE SURFACE CONTAMINATION LIMITS

(All Alpha Emitters, except U_{nat} and Th_{nat}, Considered as a Group)*

Contamination Contingencies	Limit (Activity) (dis/min-100 cm^2)+ Removable	Total (Fixed Plus Removable)
If the contaminant cannot be identified; or if alpha emitters other than U_{nat} (Note 1) and Th_{nat} are present; or if the beta emitters comprise ^{227}Ac or ^{228}Ra.	20	Nondetectable (Note 2)
If it is known that all alpha emitters are generated from U_{nat} (Note 1) and Th_{nat}; and if beta emitters are present that, while not identified, do not include ^{227}Ac, ^{125}I, ^{226}Ra, and ^{228}Ra.	200	2000 α Nondetectable β,γ (Note 3)
If it is known that alpha emitters are generated only from U_{nat} (Note 1) and Th_{nat} in equilibrium with its decay products; and if the beta emitters, while not identified, do not include ^{227}Ac, ^{125}I, ^{129}I, ^{90}Sr, ^{223}Ra, ^{228}Ra, ^{126}I, ^{131}I and ^{133}I.	1000	5000

ALTERNATE SURFACE CONTAMINATION LIMITS

*The levels may be averaged over one square meter provided the maximum activity in any area of 100 cm^2 is less than three times the limit value. For purposes of averaging with regard to isolated spots of activity, any square meter of surface shall be considered to be contaminated above the limit L, applicable to 100 cm^2, if (1) from measurements of a representative number n of sections it is determined that $1/n \sum_n S_i \geq L$, where S_i is the dis/min-100 cm^2 determined from measurement of section i; or (2) it is determined that the activity of all isolated spots or particles in any area less than 100 cm^2 exceeds 3 L.

+Disintegrations per minute per square decimeter.

NOTES:

(1) U_{nat} and decay products.

(2) The instrument utilized for this measurement shall be calibrated to measure at least 100 pCi of any Group 1 contaminants uniformly spread over 100 cm^2.

(3) The instrument utilized for this measurement shall be calibrated to measure at least 1 nCi of any Group 2 beta or gamma contaminants uniformly spread over an area equivalent to the sensitive area of the detector. Direct survey of unconditional release should be performed in areas where the background is $\leq$ 100 counts per minute. When the survey must be performed in a background exceeding 100 counts per minute, it may be necessary to use the indirect survey method to provide the additional sensitivity required.

II. GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT PRIOR TO RELEASE FOR UNRESTRICTED USE OR TERMINATION OF LICENSES FOR BY-PRODUCT SOURCE, OR SPECIAL NUCLEAR MATEIAL

(These have been retyped for purposes of this report.)

The instructions in this guide, in conjunction with Table 1, specify the radioactivity and radiation exposure rate limits which should be used in accomplishing the decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table 1 do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control will be considered on a case-by-case basis.

1. The licensee shall make a reasonable effort to eliminate residual contamination.

2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table 1 prior to applying the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.

3. The radioactivity on the interior surfaces of pipes, drain lines, or duct work shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or duct work. Surfaces of premises, equipment, or scrap which are likely to be contaminated but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement shall be presumed to be contaminated in excess of the limits.

4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with materials in excess of the limits specified. This may include, but would not be limited to, special circumstances such as razing of buildings, transfer of premises to another organization continuing work with radioactive materials, or conversion of facilities to a long-term storage or standby status. Such request must:

   a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.

b. Provide a detailed health and safety analysis which reflects that the residual amounts of materials on surface areas, together with other considerations such as prospective use of the premises, equipment or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table 1. A copy of the survey report shall be filed with the Division of Fuel Cycle and Material Safety, USNRC, Washington, D.C. 20555, and also the Director of the Regional Office of the Office of Inspection and Enforcement, USNRC, having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:

   a. Identify the premises.

   b. Show that reasonable effort has been made to eliminate residual contamination.

   c. Describe the scope of the survey and general procedures followed.

   d. State the findings of the survey in units specified in the instruction.

Following review of the report, the NRC will consider visiting the facilities to confirm the survey.

APPENDIX 6
(cont'd)

TABLE 1

ACCEPTABLE SURFACE CONTAMINATION LEVELS

NUCLIDES[a]	AVERAGE[bcf]	MAXIMUM[bdf]	REMOVABLE[bef]
U-nat, ^{235}U, ^{238}U and associated decay products	5000 dis/min-100 cm^2 α	15,000 dis/min-100 cm^2 α	1000 dis/min-100 cm^2 α
Transuranics, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{228}Th, ^{231}Pa, ^{227}Ac, ^{125}I, ^{129}I	100 dis/min-100 cm^2	300 dis/min-100 cm^2	20 dis/min-100 cm^2
Th-nat, ^{232}Th, ^{90}Sr, ^{223}Ra, ^{224}Ra, ^{232}U, ^{126}I, ^{131}I, ^{133}I	1000 dis/min-100 cm^2	3,000 dis/min-100 cm^2	200 dis/min-100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above.	5000 dis/min-100 cm^2 $\beta\gamma$	15,000 dis/min-100 cm^2 $\beta\gamma$	1000 dis/min-100 cm^2 $\beta\gamma$

TABLE 1
(Footnotes)

ACCEPTABLE SURFACE CONTAMINATION LEVELS

[a] Where surface contamination by both alpha and beta-gamma emitting nuclides exists, the limits established for alpha and beta-gamma emitting nuclides should apply independently.

[b] As used in this table, dis/min (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

[d] The maximum contamination level applies to an area of not more than 100 cm^2.

[e] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

[f] The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

III. SURGEON GENERAL'S GUIDELINES as included in 10 CFR Part 712 Grand Junction Remedial Action Criteria

712.1 Purpose

(a) The regulations in this part establish the criteria determination by DOE of the need for, priority of and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colorado, to radiation emanating from uranium mill tailings which have been used as construction-related material.

(b) The regulations in this part are issued pursuant to Pub. L. 92-314 (86 Stat. 222) of June 16, 1972.

712.2 Scope

The regulations in this part apply to all structures in the area of Grand Junction, Colorado, under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

712.3 Definitions

As used in this part:

(a) "Administrator" means the Administrator of Energy Research and Development or his duly authorized representative.

(b) "Area of Grand Junction, Colorado," means Mesa County, Colorado.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "DOE" means the U. S. Department of Energy or any duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) averaging the results of six air samples each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure approved by the Commission.

(h) "Milliroentgen" (mR) means a unit equal to one-thousandth (1/1000) of a roentgen which roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive decay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally, these include Radium A (polonium-218), Radium B (lead-214), Radium C (bismuth-214), and Radium C' (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colorado.

(l) "Surgeon General's Guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium milling operation involved in the Federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

712.4 Interpretations

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of DOE other than a written interpretation by the General Counsel will be recognized to be binding upon DOE.

712.5 Communications

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards, and Compliance, U.S. Department of Energy, Washington, D.C. 20545.

712.6 General radiation exposure level criteria for remedial action.

The basis for undertaking remedial action shall be the applicable guidelines published by the Surgeon General of the United States. These guidelines recommended the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings.

EGR	RDC	Recommendation
Greater than 0.1 mR/h	Greater than 0.05 WL	Remedial action indicated
From 0.05 to 0.1 mR/h	From 0.01 to 0.05 WL	Remedial action may be suggested.
Less than 0.05 mR/h	Less than 0.01 WL	No remedial action indicated.

712.7 Criteria for determination of possible need for remedial action

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under of adjacent to the structure, one of the following criteria is met:

(a) Where DOE approved data on indoor radon daughter concentration levels are available.

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

(b) Where DOE approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/h or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceed 0.02 mR/h above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/h above background, the indoor radon daughter concentration level is less than 0.01 WL above background, and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/h above backgrond but is less than 0.02 mR/h above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures:

(i) An external gamma radiation level of 0.15 mR/h above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

712.8 Determination of possible need for remedial action where criteria have not been met.

The possible need for remedial action may be determined where the criteria in 712.7 have not been met if various other factors are present. Such factors include but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occuping affected area, occupancy time, and use of the affected area.

712.9 Factors to be considered in determination of order of priority for remedial action.

In determining the order or priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

(a) Classification of structure. Dwellings and schools shall be considered first.

(b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in 712.7 will be considered first.

(c) Order of application. Insofar as feasible remedial action will be taken in the order in which the application is received.

(d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.

(e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.

(f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.

(g) Climatic conditions. Climatic conditions or other seasonable considerations may affect the scheduling of certain remedial measures.

712.10 Selection of appropriate remedial action.

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/h above background in the case of dwellings and schools and 0.15 mR/h above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding may be considered in addition to that of tailings removal. DOE shall select the remedial action technique or combination of techniques, which it determines to be the most appropriate under the circumstances.

IV. EXCERPTS FROM DOE 5480.1 Chg. 6, CHAPTER XI

"Requirements for Radiation Protection"

Exposure of Individuals and Population Groups in Uncontrolled Areas. Exposures to members of the public shall be as low as reasonably achievable levels within the standards prescribed below.

Radiation Protection Standards
for External and Internal Exposure
of Members of the Public

	Annual Dose Equivalent or Dose Commitment	
Type of Exposure	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on Average Dose to a Suitable Sample of the Exposed Population
Whole body, gonads, or bone marrow	0.5 rem (or 500 mrem)	0.17 rem (or 170 mrem)
Other organs	1.5 rem (or 1500 mrem)	0.5 rem (or 500 mrem)

V. EXCERPTS FROM LA-UR-79-1865-Rev., "Interim Soil Limits for D&D Projects"

Table XXIII. Recommended Soil Limits[a,b] (in pCi/g)

	Inhalation	Ingestion: Home Gardener	Ingestion: Full Diet	External Radiation	All Pathways[c]
^{231}Pa	50	740	150	250	40
^{227}Ac	200[d]	4,900	1,000	300	120[d]
^{232}Th	45	670	140	40	20
^{228}Th	1,000	37,000	7,800	55	50
^{230}Th (No Daught.)	300	4,400	940	36,000	280
^{238}U-^{234}U	750	44	8	6,000	40
^{90}Sr	$2x10^6$	100	19	-	100
^{137}Cs	$7x10^6$	800	1	90	80

[a]Soil limits for ^{241}Am and $^{239,240}Pu$ are available from EPA recommendations, and a soil limit for ^{226}Ra has been reported by Healy and Rodgers.

[b]Limits are to apply to only one nuclide present in the soil. If more than one is present a weighted average should apply.

[c]Based on diet of a home gardener.

[d]Modified from LA-UR-79-1865-Rev. values to correct apparent error.

APPENDIX 7

DOSE-DETERMINATION CALCULATIONS

To assess the internal radiological hazard from inhalation/ingestion of contamination possibly due to MED/AEC occupancy, a hypothetical, yet conceivable, worst-case situation involving the ceiling in Room 1 has been constructed. Since the results of gamma-spectral and mass-spectral analysis indicated normal uranium, normal uranium has been used as the nuclide of concern in the scenario that follows.

The highest level of contamination on the ceiling of Room 1 (at location 133) was 1.7×10^5 dis/min-100 cm^2 equated to normal uranium. The activity (A) in units of µCi is:

$$A = 1.7 \times 10^5 \text{ dis/min-100 cm}^2 \times \frac{1 \text{ Ci of normal U*}}{4.54 \times 10^{12} \text{ dis/min}} \times \frac{10^6 \ \mu\text{Ci}}{1 \text{ Ci}}$$

$$= 3.74 \times 10^{-2} \ \mu\text{Ci/100 cm}^2.$$

A probable situation that could arise would involve the cutting of the ceiling for an exhaust vent using a concrete-core driller. Since much of the ceiling was contaminated, it is assumed that the entire area of the ceiling being cut is uniformly contaminated at a level of 3.74×10^{-2} µCi/100 cm^2. It also is assumed that a concrete-core driller having a diameter of 30.5 cm (1 ft) and a cutting edge of 1.5 cm is used to cut the holes. The area of concrete (B) displaced by the driller would be:

$$B = \pi[(15.2 \text{ cm})^2 - (13.7 \text{ cm})^2] = 1.36 \times 10^2 \text{ cm}^2.$$

It is assumed that the concrete is dry and that a maximum dust disturbance would be created. Since the cutting operation would probably produce many small particles (or dust) of concrete rather than large pieces, the assumption is made that 90% of the concrete becomes airborne and respirable. The total amount of activity that becomes airborne and respirable (C) due to the cutting is then:

$$C = 3.74 \times 10^{-2} \ \mu\text{Ci/100 cm}^2 \times 1.36 \times 10^2 \text{ cm}^2 \times 0.90$$

$$= 4.59 \times 10^{-2} \ \mu\text{Ci}$$

The total volume of Room 1 is about 2.2×10^3 m^3. If the dust created would become dispersed throughout the room and suspended in this volume of air, the concentration of normal uranium in the air (D) would be:

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*A Curie of normal uranium normalized to ^{238}U, i.e., the sum of 3.7×10^{10} dis/s from ^{238}U, plus 3.7×10^{10} dis/s from ^{234}U, plus 1.7×10^9 dis/s from ^{235}U. This equals 7.57×10^{10} dis/s or 4.54×10^{12} dis/min. A standard Curie is 3.7×10^{10} dis/s or 2.22×10^{12} dis/min.

$D = 4.59 \times 10^{-2}$ µCi/2.2×10^{3} m^3

$= 2.1 \times 10^{-5}$ µCi/m^3.

More than two people would probably not be involved in this operation, and the job should require no more than an hour. The drilling of this small area should not take very long and the particles would soon fall out of suspension. Assuming a person would inhale 1.2 m^3 of air per hour (Ref. 1) and would be involved in this job for a one-hour period, the amount of activity (E) that would be inahled is:

$E = 2.1 \times 10^{-5}$ µCi/m^3 x 1.2 m^3/h x 1 h

$= 2.5 \times 10^{-5}$ µCi

$= 2.5 \times 10^{1}$ pCi.

The adult inhalation dose commitment factors for the bone, kidney, lung, and total body from ^{238}U, ^{234}U, ^{235}U, and short-lived daughters (Ref. 2) are presented in Table 7.1. The sum of the factors for ^{238}U and ^{234}U and short-lived daughters is also presented. The results of the calculations given in Appendix 5, i.e., that 2.2% of normal U disintegrations per minute are due to ^{235}U and 97.8% due to $^{238,234}U$ (or 48.9% each) can be used to obtain the dose commitment factors for normal uranium in terms of pCi of ^{238}U.

The 50-year dose commitment (F) from the inhalation of 2.5×10^{1} pCi of normal uranium is:

$F = 2.5 \times 10^{1}$ pCi x

(1) 1.0×10^{-1} mrem/pCi inhaled = 2.5 mrem, lung

(2) 2.04×10^{-2} mrem/pCi inhaled = 5.1×10^{-1} mrem, bone

(3) 4.78×10^{-3} mrem/pCi inhaled = 1.2×10^{-1} mrem, kidney

(4) 1.24×10^{-3} mrem/pCi inhaled = 3.1×10^{-2} mrem, total body

Thus, the person would receive a 2.5-mrem dose commitment to the lung, a 0.51-mrem dose commitment to the bone, a 0.12-mrem dose commitment to the kidneys, and a 0.031-mrem dose commitment to the total body under this scenario.

Even though these calculations are based on reasonable hypothesized values, the actual total inhaled and the subsequent dose commitments could differ from those hypothesized. This is due to uncertainties in the estimation of the fraction that becomes airborne and respirable, in the estimation of the breathing rate and duration of inhalation, and in the application of the dose commitment factors to the persons involved. The hypothesized case is, however, based on reasonably conservative assumptions.

APPENDIX 7
(cont'd)

TABLE 7.1

ADULT DOSE COMMITMENT FACTORS
(mrem/50 yr-pCi inhaled in the 1st year)

Radionuclide	Bone	Kidney	Lung	Total Body
^{238}U	9.58×10^{-3}	2.18×10^{-3}	4.58×10^{-2}	5.67×10^{-4}
^{234}Th	1.63×10^{-6}	5.41×10^{-7}	1.89×10^{-4}	4.7×10^{-8}
^{234}U	1.04×10^{-2}	2.49×10^{-3}	5.22×10^{-2}	6.46×10^{-4}
^{235}U	1.0×10^{-2}	2.34×10^{-3}	4.90×10^{-2}	6.07×10^{-4}
^{234}U & ^{238}U & short-lived daughters (per pCi of ^{238}U)	2.0×10^{-2}	4.67×10^{-3}	9.82×10^{-2}	1.21×10^{-3}
Normal U[a] (per pCi of ^{238}U)	2.04×10^{-2}	4.78×10^{-3}	1.0×10^{-1}	1.24×10^{-3}

[a]Normal U is 2.2% ^{235}U and 97.8 ^{234}U and ^{238}U, by pCi (see Appendix 5).

REFERENCES FOR APPENDIX 7

1. Bureau of Radiological Health. 1970. "Radiological Health Handbook." Rev. ed., pg. 216

2. Holmes, G. R. and J. K. Soldat. 1977. "Age Specific Radiation Dose Commitment Factors for a One Year Chronic Intake." NUREG-0172, U.S. Nuclear Regulatory Commission, pg. 39.

APPENDIX 8

EVALUATION OF RADIATION EXPOSURES AT THE NATIONAL GUARD ARMORY

I. PREFACE

The U.S. Department of Energy has initiated a program to determine the present radiological condition of sites formerly used for work with radioactive material by the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC). Beginning in March 1942, the Illinois National Guard Armory at Washington Park, 52nd Street and Cottage Grove Avenue, Chicago, Illinois, was used jointly by the MED Metallurgical Laboratory and the University of Chicago. Personnel involved with this facility during the MED/AEC era recalled that some type of uranium processing was conducted there and that the grandstands surrounding the arena were used for storage of radioactive materials. The use of the arena could have involved both the chemical processing and metal casing of uranium. The use of the facility was terminated in 1951 and the property returned to the State of Illinois. Since existing documentation was insufficient to determine whether any decontamination work done at the time nuclear activities ceased was adequate by current guidelines, a comprehensive radiological assessment of the armory was conducted during the period September 19, 1979, to October 11, 1978.

The Illinois National Guard Armory is a 70 m x 190 m concrete building. The arena, which is 70 m x 110 m, is located on the first floor; the areas surrounding the arena are three stories high. The armory is occupied by the Illinois National Guard and houses the 1st Battalion, 178th Infantry, and the 2nd Battalion, 122nd Field Artillery. It is used for offices, classrooms, and storage and garage areas.

II. INTRODUCTION

A. Types of Radiation

Radiation is the emission or transmission of energy in the form of waves or particles. Examples are acoustic waves (i.e., sound), electromagnetic waves (such as radio, light, x- and gamma-rays), and particulate radiations (such as alpha particles, beta particles, neutrons, protons, and the elementary particles).

The class of radiation of importance to this report is known as ionizing radiation. Ionizing radiations are those, either electromagnetic or particulate, with sufficient energy to ionize matter, i.e., to remove or displace electrons from atoms and molecules. The most common types of ionizing radiation are x- and gamma-rays, alpha particles, beta particles, and neutrons.

X- and gamma-rays are electromagnetic waves of pure energy, having no charge and no mass or existence at rest. Gamma-rays and x-rays are identical except that x-rays originate in the atom and gamma-rays originate in the nucleus of an atom. X- and gamma-rays are highly penetrating and can pass through relatively thick materials before interacting. Upon interaction, some or all of the energy is transferred to electrons, which, in turn, produce additional ionizations while coming to rest.

Alpha particles are positively charged particulates composed of two neutrons and two protons, identical to the nucleus of a helium atom. Due to its comparatively large mass and double charge, an alpha particle interacts readily with matter and penetrates only a very short distance before coming to rest, causing intense ionization along its path.

Beta particles are negatively charged free electrons moving at high speeds. Due to its comparatively small mass and single charge, a beta particle's penetration through matter is intermediate between that of the alpha particle and the gamma-ray, causing fewer ionizations per unit path length than an alpha particle.

B. Sources of Radiation

Ionizing radiations arise from terrestrial radioactive materials (both naturally-occurring and man-made), extra-terrestrial (cosmic) sources, and radiation-producing machines. The sources of ionizing radiation important to this report are radioactive materials and cosmic sources.

Most atoms of the elements in our environment remain structurally stable. With time, an atom of potassium, for instance, may change its association with other atoms in chemical reactions and become part of other compounds, but it will always remain a potassium atom. Radioactive atoms, on the other hand, are not stable and will spontaneously emit radiation in order to achieve a more stable state. Through spontaneous transformation, the ratio of protons and neutrons in the nucleus is altered toward a more stable condition. Radiation may be emitted from the nucleus as alpha particles, beta particles, neutrons, or gamma-rays, depending uniquely upon each particular radionuclide. Radionuclides decay at characteristic rates dependent upon the degree of stability and characterized by a period of time called the half-life. In one half-life, the number of radioactive atoms and, therefore, the amount of radiation emitted, decreases by one-half.

The exposure of man to terrestrial radiation is due to naturally occuring radionuclides and also to "man-made" or technologically enhanced radioactive materials. Several dozen radionuclides occur naturally, some having half-lives of at least the same order of magnitude as the estimated age of the earth. The majority of these naturally occurring radionuclides are isotopes of the heavy elements and belong to three distinct radioactive series headed by uranium-238, uranium-235, and thorium-232. Each of these decays to stable isotopes of lead (Pb) through a sequence of radionuclides of widely varying half-lives. Other naturally occurring radionuclides, which decay directly to a stable nuclide, are potassium-40 and rubidium-87. It should be noted that even though the isotopic abundance of potassium-40 is less than 0.012%, potassium is so widespread that potassium-40 contributes about one-third of the radiation dose received by man from natural background radiation. A major portion of the exposure (dose) of man to external terrestrial radiation is due to the radionuclides in the soil, primarily potassium-40 and the radioactive decay chain products of thorium-232 and uranium-238. The naturally occurring radionuclides deposited internally in man through uptake by inhalation/ingestion of air, food, and drinking water containing the natural radioactive material also contribute significantly to his total dose. Many other radionuclides are referred to as "man made" in the sense that they can be produced in large quantities by such means as nuclear reactors, accelerators, or nuclear weapons tests.

The term "cosmic radiation" refers both to the primary energetic particles of extra-terrestrial origin that are incident on the earth's atmosphere and to the secondary particles that are generated by the interaction of these primary particles with the atmosphere and reach ground level. Primary radiation consists of "galactic" particles, externally incident on the solar system, and "solar" particles emitted by the sun. This radiation is composed primarily of energetic protons and alpha particles. The first generation of secondary particles (secondary cosmic radiation), produced by nuclear interactions of the primary particles with the atmosphere, consists predominantly of neutrons, protons, and pions. Pion decay, in turn, results in the production of electrons, photons, and muons. At the lower elevations, the highly penetrating muons and their associated decay and collision electrons are the dominant components of the cosmic-ray particle flux density. These particles, together with photons from the gamma-emitting, naturally occurring radionuclides in the local environment, form the external penetrating component of the background environmental radiation field which produces a significant portion of the whole-body radiation dose to man.

In addition to the direct cosmic radiation, cosmic sources include cosmic-ray-produced radioactivity, i.e., cosmogenic radionuclides. The major production of cosmogenic radionuclides is through interaction of the cosmic rays with the atmospheric gases through a variety of spallation or neutron-capture reactions. The four cosmogenic radionuclides that contribute a measurable radiation dose to man are carbon-14, sodium-22, beryllium-7, and tritium (hydrogen-3), all produced in the atmosphere.

III. BACKGROUND RADIATION DOSES

Background radiation doses are comprised of an external component of radiation impinging on man from outside the body and an internal component due to radioactive materials taken into the body by inhalation or ingestion.

Radiation dose may be expressed in units of rads or rems, depending upon whether the reference is to the energy deposited or to the biological effect. A rad is the amount of radiation that deposits a certain amount of energy in each gram of material. It applies to all radiations and to all materials which absorb that radiation.

Since different types of radiation produce ionizations at different rates as they pass through tissue, differences in damage to tissues, and hence the biological effectiveness of different radiations, has been noticed. A rem is defined as the amount of energy absorbed (in rads) from a given type of radiation multiplied by the factor appropriate for the particular type of radiation in order to approximate the biological damage that it causes relative to a rad of x or gamma radiation. The rem permits evaluation of potential effects from radiation exposure without regard to the type of radiation or its source. One rem received from cosmic radiation results in the same biological effects as one rem from medical x-rays or one rem from the radiations emitted by naturally occurring or man-made radioactive materials.

The external penetrating radiation dose to man derives from both terrestrial radioactivity and cosmic radiation. The terrestrial component is due primarily to the gamma dose from potassium-40 and the radioactive decay products of thorium-232 and uranium-238 in soil as well as from the beta-gamma dose from radon daughters in the atmosphere. Radon is a gaseous member of the uranium-238 chain. The population-weighted external dose to an individual's whole body from terrestrial sources in the United States has been estimated as 15 mrem per year for the Atlantic and Gulf Coastal Plain, 57 mrem per year for an indeterminate area along the Rocky Mountains, and 29 mrem per year for the majority of the rest of the United States. The overall population-weighted external dose for the U.S. population as a whole has been estimated to be 26 mrem per year.

The cosmic radiation dose, due to the charged particle and neutrons from secondary cosmic rays, is typically about 30% to 50% of the total from all external environmental radiation. The cosmic-ray dose to the population is estimated to be 26 mrem per year for those living at sea level, and increases with increasing altitude. Considering the altitude distribution of the U.S. population, the population-weighted external cosmic-ray dose is 28 mrem per year. The population-weighted total external dose from terrestrial plus cosmic sources is thus 54 mrem per year for the U.S. population as a whole.

The internal radiation doses derive from terrestrial and cosmogenic radionuclides deposited within the body through uptake by inhalation/ingestion of air, food, and drinking water. Once deposited in the body, many radioactive materials can be incorporated into tissues because the chemical properties of the radioisotopes are identical or similar to stable isotopes in the tissues. Potassium-40, for instance, is incorporated into tissues in the same manner as stable potassium atoms because the chemical properties are identical; radioactive radium and strontium can be incorporated into tissues in the same manner as calcium because their chemical properties are similar. Once deposited in tissue, these radionuclides emit radiation that results in the internal dose to individual organs and/or the whole body as long as it is in the body.

The internal dose to the lung is due primarily to the inhalation of polonium-218 and -214 (radon daughters), lead-212 and bismuth-212 (thoron daughters) and polonium-210 (one of the longer-lived radon decay products). The dose to the lung is about 100 mrem per year from inhaled natural radioactivity. The internal dose from subsequent incorporation of inhaled or ingested radioactivity is due to a beta-gamma dose from incorporation of potassium-40, rubidium-87, and cosmogenic nuclides, and an alpha dose from incorporation of primarily polonium-210, radium-226 and -228, and uranium-238 and -234. The dose to man from internally incorporated radionuclides is about 28 mrem per year to the gonads, about 25 mrem per year to the bone marrow, lung, and other soft tissues, and about 117 mrem per year to the bone (osteocytes). The bone dose arises primarily from the alpha-emitting members of the naturally occurring series, with polonium-210 being the largest contributor. The gonadal and soft tissue doses arise primarily from the beta and gamma emissions from potassium-40. The total internal dose from inhaled plus incorporated radioactivity is about 28 mrem per year to the gonads (or whole-body dose), about 125 mrem per year to the lung, about 25 mrem per year to the bone marrow, and about 117 mrem per year to the bone (osteocytes).

The total natural background radiation dose is the sum of the external and internal components. The population-weighted dose for the U.S. population as a whole is about 82 mrem per year to the gonads or whole body, about 179 mrem per year to the lung, about 79 mrem per year to the bone marrow, and about 171 mrem per year to the bone (osteocytes) (Ref. 1).

Besides the natural background radiation, background radiation doses include contributions from man-made or technologically enhanced sources of radiation. By far, the most significant are x-ray and radiopharmaceutical medical examinations. These contribute a population-averaged dose estimated to be 70 mrem per year for the U.S. population as a whole. Fallout from nuclear weapons testing through 1970 has contributed 50-year dose commitments estimated as 80 mrem external, and 30, 20, and 45 mrem internal to the gonads, lung, and bone marrow, respectively. Contributions from the use of fossil fuels (natural gas and coal) and nuclear reactors; mining, milling, and tailings piles; television sets, smoke detectors, and watch dials could be responsible for an additional 5 mrem per year, averaged over the U.S. population as a whole. In addition, the use of radiation or radioactivity for scientific, industrial, or medical purposes may cause workers in the industry and, to a lesser extent, members of the general public to receive some radiation exposure above natural background.

IV. EVALUATION OF RADIATION DOSE AND POTENTIAL HAZARD

Radiation, regardless of its sources, is considered to be a hazard because of its potential for producing adverse effects on human life. Very large amounts of radiation received over a brief period, i.e., hundreds of rem delivered within a few hours, can produce severe injury or death within days or weeks. Distributed over longer intervals, however, these same doses would not cause early illness or fatality. At doses and rates too low to produce these immediate symptoms, chronic or repeated exposure to radiation can bring about biological damage which does not appear until years or decades later. These low-level effects are stochastic in nature; their probability rather than their severity increases with dose. Primary among these latent or delayed effects are somatic effects, where insults such as cancers occur directly to the individual exposed, and genetic defects, where, through damage to the reproductive cells of the exposed individual, disability and disease ranging from subtle to severe are transmitted to his offspring.

Clinical or observed evidence of a relationship between radiation and human cancers arise from several sources. The most important data come from the victims of Hiroshima and Nagasaki, patients exposed during medical therapy, radium dial painters, and uranium miners. Data exist only for relatively large doses; there have been no direct measurements of increased incidence of cancer for low-level radiation exposures. Evaluation of the available data has lead to estimates of the risk of radiation-induced cancer; estimated risks for the lower doses have been derived by linear extrapolation from the higher doses. All radiation exposures then, no matter how small, are assumed to be capable of increasing an individual's risk of contracting cancer.

Data on genetic defects resulting from radiation exposure of humans is not available to the extent necessary to allow an estimate of the risk of radiation-induced effects. Data from animals, along with general knowledge of genetics, have been used to derive an estimate of the risks of genetic effects.

Estimates of health effects from radiation doses are usually based on risk factors as provided in reports issued by International Commission on Radiological Protection (ICRP) (Ref. 2), National Research Council Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) (Refs. 3, 4), or United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (Ref. 5). Multiplying the estimated dose by the appropriate risk factor provides an estimate of the risk or probability of induction of health effects to an individual or his descendants as a result of that exposure. The evaluation of these risk factors is presently subject to large uncertainties and, therefore, potential continual revision. The risk factors recommended by the ICRP for cancer mortality and hereditary ill health to the first and second generations are 10^{-4} per rem of whole-body dose and 4×10^{-5} per rem of gonadal dose, respectively. As an example, a whole-body dose of 1 rem would be estimated to add a risk of cancer mortality to the exposed invididual of 10^{-4}, i.e., 1 chance in 10,000. However, a precise numerical value cannot be assigned with any certainty to a particular individual's increase in risk attributable to radiation exposure. The reasons for this are numerous and include the following: (1) uncertainties over the influence of the individual's age, state of health, personal habits, family medical history, and previous or concurrent exposure to other cancer-causing agents, (2) the variability in the latent period (time between exposure and physical evidence of disease), and (3) the uncertainty in the risk factor itself.

To be meaningful, an attempt should be made to view such risk estimates in the appropriate context. One useful comparison is with risks encountered in normal life. Another comparison, potentially more useful, is with an estimation of the risks attributable to natural background radiation. Radiation from natural external and internal radioactivity results in the same types of interactions with body tissues as that from "man-made" radioactivity. Hence, the risks from a specified dose are the same regardless of the source. Rather than going through an intermediate step involving risk factors, doses can also be compared directly to natural background radiation doses.

Besides being used as the basis for estimation of risks and comparisons to natural background, doses may be compared to standards and regulations. The appropriate standards, the Department of Energy "Requirements for Radiation Protection," give limits for external and internal exposure for the whole body and specified organs which are expressed as the permissible dose or dose commitment annually in addition to natural background and medical exposures. There are in general two sets of limits, one applicable to occupationally exposed persons and the second applicable to individuals and population groups of the general public. The limits for individuals of the public are one-tenth of those permitted for occupationally exposed individuals. The set of limits important to this report are those applicable to individuals and population groups of the public. The limits for individuals of the public are 500 mrem per year to the whole body, gonads, or bone marrow and 1500 mrem per year to other organs. The limits for population groups of the public are 170 mrem to the whole body, gonads, or bone marrow and 500 mrem per year to other organs, averaged over the group. In either case, exposures are to be limited to the lowest levels reasonably achievable within given limits.

V. RESULTS OF SITE RADIOLOGICAL SURVEY

The comprehensive radiological survey performed at the Illinois National Guard Armory was conducted on an intermittent basis between September 1977 and October 1978. Direct instrument surveys and smear surveys indicated that some areas of contamination were present in the facility. Contamination possibly due to MED/AEC occupancy was found at 73 locations in 11 rooms or areas. With the exception of Rooms 1, 260, and the floor drain system for Rooms 1 and 5, the contamination consisted of small localized spots, mainly on floors. The contamination in Room 1 was extensive and involved about 200 m^2 of concrete ceiling and floor. The contamination in Room 260 involved about 3 m^2 of concrete floor. The contamination on the floors was not easily removable, whereas most of the contamination on the ceiling was easily removable when smeared. The contamination in the floor drain system for Rooms 1 and 5 consisted of about 2 m^2 of contaminated brick and sludge within two catch basins. Gamma-spectral analyses indicated that the contaminant is predominantly normal uranium. Air sampling indicated ranges of radon and daughter concentrations within normally expected background concentrations. No long-lived radionuclides were detected on any air sample. Environmental soil sampling about the grounds of the National Guard Armory indicated uranium concentrations essentially the same as natural background.

The survey data may be evaluated in terms of the potential doses that exposed persons could receive. Doses were calculated for a scenario involving the ceiling in Room 1 that could result in an internal radiation dose from inhalation of radioactivity. The maximum potential internal dose was calculated to be 2.5 mrem to the lung, 0.51 mrem to the bone, 0.12 mrem to the kidney, and 0.031 mrem to the whole body. For the lung, bone, and kidney, these doses represent additions of about 1.4%, 0.3% and 0.15%, to the 179-mrem, 171-mrem, and 82-mrem annual natural background lung, bone, and kidney (soft tissue) doses, respectively, and 0.2%, 0.03% and 0.008% of the 1500-mrem limit for a member of the public. For the whole body, this represents an increase of about 0.04% to the 82-mrem annual natural background whole body dose and 0.006% of the 500-mrem limit for a member of the public.

To reduce the potential for radiation exposures, remedial measures such as stabilization of the contamination in place would be applicable as a short-term measure. To reduce the risk in the event that building modifications take place in the future, health physics procedures and coverage are recommended. The long-term solution would involve decontamination by removal of the radioactive residues from the 11 rooms or areas in the facility.

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